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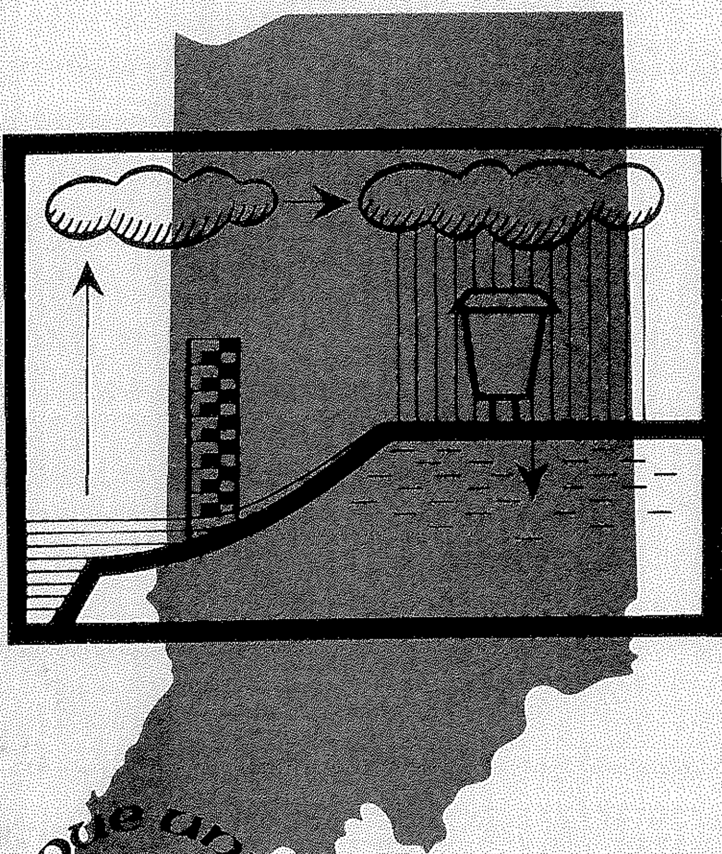
SYSTEMATIC DEVELOPMENT OF METHODOLOGIES IN PLANNING URBAN WATER RESOURCES FOR MEDIUM SIZE COMMUNITIES

Benefits and Costs of Storm Drainage Systems



by

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September 1975

PURDUE UNIVERSITY
WATER RESOURCES RESEARCH CENTER
WEST LAFAYETTE, INDIANA

BENEFITS AND COSTS OF STORM DRAINAGE SYSTEMS

by

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This is a partial completion report contributing to the project entitled "Systematic Development of Methodologies in Planning Urban Water Resources for Medium Size Communities."

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Foreword

This report is based upon the research conducted by Mr. Keith M. Naber and reported in his Master of Science thesis. It is the second report on the economic aspects of drainage under this contract. The first report entitled "Economic and Environmental Impacts of Surface Runoff Disposal Systems" by W. L. Miller and S. P. Erickson was published as Technical Report No. 39 of the Purdue University Water Resources Research Center. The first report compared alternative drainage system designs to indicate the least cost systems which would provide specified levels of water quality.

This second report complements the first study by concentrating on development of better benefit estimates by measuring the flood damage in a flood prone residential area through survey data based on sale prices of homes. Together the two reports provide detailing information on both the benefits and costs of storm drainage systems in residential areas.

The authors appreciate the assistance of Robert L. Meyers, Jr. and Don Semler, staff appraisers with the Henry County Savings and Loan Association in the collection of primary data. Tony Drost, an appraiser in Anderson, Indiana, helped us with the survey of flood prone and nonflood prone areas. Bob Rades and Martin Pond provided incisive comments which greatly improved this research. The interdisciplinary research committee on the Urban Project provided essential input to our study. In addition we appreciate the financial assistance of the Office of Water Resources Research, Department of Interior, and the Department of Agricultural Economics, Purdue University.

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CHAPTER I

INTRODUCTION

The percentage of the U.S. population living in urban areas has been steadily increasing over the last decade. The two main causes of the increase are the continuing migration of people from rural to urban areas and the general population growth. As urban populations have increased, more and more space is required for residential use. This is due partly to the general growth in urban populations and partly to the out-migration of residents from the inner-city to suburban areas. The result has been a rapid expansion in the suburban residential areas of many cities.[1]

This rapid suburban expansion has not always taken place without problems. Newly developed suburban areas require the provision of many public services. These include the provision of adequate water supplies, police and fire protection, sanitary sewers, and storm sewers. Storm sewers are not legally required in urban residential areas at this time, however,

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1 The Bureau of the Census reports that the population of metropolitan areas in each region of the U.S. increased between 1960-1969 by an average of 16.2%. The population of the central cities did not change significantly while the population of suburban areas increased by an average of 31.2%.

they are often provided and found to be extremely beneficial in areas where topographical characteristics do not allow for the natural removal of storm water. The primary objective of this study is to determine the benefits of adequate drainage and to compare these benefits with the costs of providing the service.

The Use of Benefit-Cost Analysis

Traditionally, maximization of national income was the criterion used in project analysis. This criterion has largely been abandoned due to the close association between national income measurement and prevailing market values.[2] Economic efficiency has replaced national income as a superior criterion to measure project effectiveness. The objective of maximizing economic efficiency has become an increasingly popular criterion as competition for scarce funds becomes more acute. "It is the efficiency objective that is typically identified with benefits and costs."[3]

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[2] The point is illustrated by Marglin using the following example: "..if a water-resource development made great amounts of electrical energy available for residential consumers at a low cost, it would add more to the size of the economic pie than another development scheme which made smaller amounts available at a higher cost, even if the national income value of the latter scheme measured at market prices were to be higher than the former." Marglin, Stephen A., "Objectives of Water-Resource Development: A General Statement" in Design of Water Resource Systems, Maas, Jufschmidt, Dorfman, Thomas, Marglin, and Fair, Harvard University Press, Cambridge, Massachusetts, 1962, p.20.

[3] Ibid., p.20.

Benefit-cost analyses are attempts to estimate certain gains and losses that would result from taking alternative courses of action. All such analyses involve working with certain common elements. These are: "(1) objectives, or beneficial things, to be achieved; (2) alternatives, or possible systems or arrangements for achieving the objectives; (3) costs, or the benefits that must be forgone if one of the alternatives is adopted; (4) models, or the sets of relationships that help trace out the impacts of each alternative on achievements (in other words, on benefits) and costs; and (5) a criterion, involving both benefits and costs, to identify the preferred alternative."[4]

The development of methodologies to properly evaluate benefits and costs has been and is continuing to be investigated. No guidelines have been firmly established concerning what criteria shall be used to measure benefits and costs.[5] Also, the question of how limited resources should be allocated between the public and private sectors has not been answered. These types of considerations must, to a large extent, be dealt with by the researcher himself.

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4 McKean, Roland N., "The Nature of Cost-Benefit Analysis", in Microeconomics - Selected Readings, W.W. Norton & Co. Inc., New York, 1971, p. 340.

5 For example, the standard set forth in the Flood Control Act of 1936 for evaluating water development proposals, that "the benefits to whomsoever they may accrue are in excess of the estimated costs" gives no guidance as to the type of benefits to be measured.

One important application of the benefit-cost analysis is in the evaluation of public water resource projects. Naturally, it is important to consider all the benefits and costs when evaluating public projects, however, some measurement problems do exist. There are several types of benefits and costs that must be recognized, each requiring a different method of estimation. Consider the following categories: (1) benefits and costs that can be measured in monetary units; (2) other commensurable effects, such as higher salaries; (3) incommensurable effects that can be quantified, but not in terms of a common denominator (units of air pollution, for example, can be determined, but a dollar value is difficult to attach); and (4) non-quantifiable effects, such as aesthetic enhancement.[6]

This distinction between categories of benefits and costs is useful in determining the limitations of benefit-cost analysis. Clearly, some resource related projects do not lend themselves as well to the benefit-cost technique as a measure of economic efficiency as do others. Environmental quality, for example, is often an extremely important objective in many resource related projects. Benefits from pollution abatement, however, are very difficult to quantify in terms of dollars. Other social objectives, such as aesthetic enhancement and income distribution, present similar difficulties.

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[6] This topic is discussed by McKean, op. cit., p. 344.

In some cases, the benefits can be quantified in terms of non-monetary units to be compared with the associated costs. The form of the non-monetary unit to be evaluated can be most easily determined when considering comparatively narrow problems of choice. With such a problem, the consequences of a particular action, or investment, can be presented in terms of values that people can agree are at stake.[7] This allows a trade-off relationship to be developed, providing the public and planners a basis with which to make decisions regarding proposed public investments.

The benefit-cost analysis, then, does not necessarily require that benefits and costs be quantified in terms of dollars to be useful as an evaluational tool. However, since the presentation of benefits and costs in dissimilar units does require that a subjective, or value, judgement be made, the direct dollar comparison of all benefits and costs is the optimal situation and should be used whenever possible.

The Case of Urban Storm Drainage

Inadequate storm drainage is an acute problem in many urban areas. In some cases, poor planning has resulted in the location of residential areas on poorly drained, flood-prone land without installation of the necessary storm drainage facilities. In other cases, residential areas have developed

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[7] Discussed by McKean, op. cit., p. 347.

outside of city limits where cities have had no juristiction to regulate land use. These situations have resulted in property damages and inconveniences to property owners as well as to other residents of the community. Some cities, with new impetus resulting from the availability of federal funds for storm drainage runoff systems and sewage treatment plants, have developed comprehensive programs to eliminate the flooding hazard in their residential areas. Other cities have seemingly ignored, or at least postponed, storm drainage investments in favor of other public investments perhaps more publicized or more glamorous in nature. This study will focus on the advisability of providing storm drainage relief to flood-prone residential areas, using economic efficiency as the criterion.

There has been a considerable amount of effort expended in the measurement of storm runoff and in developing and evaluating alternative drainage system designs to adequately carry storm runoff. Measuring the cost of a particular drainage proposal, then, is relatively easy. There has not been a similar effort made to measure the benefits of adequate drainage, however. In order to apply the benefit-cost analysis to this problem, some measurement of the benefits must be made.

The damages of inadequate storm drainage take several forms. The ponding and back-up of storm runoff in a residential area may result in damages to the house, the yard, and the street. These damages, which are quantifiable in terms of dollars, may or may not represent the bulk of flood-related damages. Other damages, such as inconvenience to motorists forced to detour around flooded areas, possible health hazards to local residents, and the deterioration of the aesthetic beauty of a neighborhood are damages which may be very important, but which cannot be easily quantified. These damages are referred to as incommensurable, or non-measurable, damages, the value of which must normally be evaluated on a subjective basis. Since damages are losses to society, the elimination of these damages may be regarded as the benefits.

This analysis will initially examine the extent to which purchasers of residential property discount the value of property located in inadequately drained residential areas. This discount will be interpreted as the expected damage estimate. The elimination of these damages will be regarded as the benefits of providing adequate drainage. The analysis will then be expanded to include drainage system costs. Only the costs of a pipeline drainage system will be calculated since open-channel systems are only occassionally used in residential areas. Finally, the costs and the benefits will be compared providing a measure of economic efficiency. The procedures and the programming model used to estimate the benefits and the method used to estimate the costs will be useful to city planners and decision-makers in evaluating proposed storm drainage projects.

The assumption made for this study is that planners and decision-makers are concerned not only with the costs of providing storm drainage, but also with the benefits that can be expected to result. If the benefits can be determined and compared with the costs, a valid determination of the economic efficiency of a proposed project can be made.

Objectives of the Study

(1) To estimate the benefits that would result from providing adequate storm drainage to flood-prone residential areas.

(2) To compare the benefits of adequate storm drainage with the costs of providing the drainage system, thus providing a framework with which to measure economic efficiency.

(3) To illustrate and compare the benefit-cost analysis of providing an adequate storm drainage system to an area before urbanization has begun with the benefit-cost analysis of providing the same system after urbanization has been completed.

The following chapters will include the following topics: Chapter II will develop theoretical considerations relevant to this study. This chapter will include sections discussing how prices are determined under perfect competition, the concept of economic rent, and a discussion of linear regression analysis. Chapter III will contain an in-depth description of the case study area and the present system of storm drainage. Chapter IV includes sections outlining the sources of data and the procedures used in this analysis, the programming model used to estimate the benefits, the empirical results of the model, and a section devoted to calculating and comparing these costs with the benefits. Chapter V will summarize the results of the study, state conclusions and implications of the analysis, indicate limitations of the results, and provide suggestions for further research.

CHAPTER II

THEORETICAL CONSIDERATIONS AND THE PROGRAMMING FRAMEWORK

The purpose of this chapter is to develop theoretical considerations relevant to the problem under study. There are three sections contained in this chapter. They include: the theory of supply, demand and equilibrium, the concept of economic rent, and a review of the theory and assumptions of linear regression analysis.

For the concept of economic efficiency to be useful as a decision-making criterion, some measurement of the benefits and costs must be made. In this study, residential property values will be used as a measure of the utility, or satisfaction, that property owners attach to various residential properties. Property value change is a valid reflector of the value that people attach to urban improvements, such as storm drainage improvements. If people regard adequate storm drainage as an asset to their property, it can be assumed that they will be willing to pay more for property located in an area where adequate drainage exists. The additional amount that people are willing to pay can be determined by comparing the selling prices of land and improvements in poorly drained areas with the selling prices in well-drained areas, *ceteris paribus*. The total homeowner benefits of adequate drainage can then be expressed as the difference in sale value of homes similar in physical characteristics, but different with respect to drainage adequacy. Costs will be measured as the price that must be paid by society to achieve the objective of adequate storm drainage.

For sale value to be a valid indicator of utility, it must be assumed that the housing market is perfectly competitive. Perfect competition requires the following assumptions:

1. There are a large number of buyers and sellers, none of which can significantly affect the market,
2. The product involved is sufficiently homogenous,
3. The buyers and sellers have perfect information.

It is further assumed in this study that buyers behave in a rational way. That is, that buyers pay more for property that sustains the least physical damage and causes them the least inconvenience.

It is believed that the first assumption is met. No evidence has been found to indicate that there are any predominant buyers or sellers in the housing market that can, by themselves, influence sale values. The second assumption involving homogeneity is met to the extent that the residences sampled in this analysis were relatively similar in terms of general physical characteristics. However, they varied with respect to drainage adequacy. The extent that this factor influences sale value is the subject of this analysis. It is unknown to what extent the third assumption is met. There is some suspicion that home-buyers do not, in every case, enjoy perfect information. However, there is no concrete evidence to support this suspicion. Therefore, it will be assumed for this analysis that buyers are sufficiently knowledgeable about the property they purchase to meet this assumption.

Supply, Demand, and Equilibrium

The purpose of this section is to discuss how market prices are determined under perfect competition. This concept is essential in understanding how residential property buyers will behave given various market conditions.

The competitive market price, or the equilibrium price, is that price at which the amount willingly supplied and the amount willingly demanded are equal. Thus, the competitive equilibrium must be at the point where the supply and demand curves intersect. This simple relationship is depicted in Figure 2.1. The equilibrium price is P_o and the equilibrium quantity supplied is Q_o.

The supply and demand curves need not remain fixed. The location and shape of the demand curve will depend on the consumers' level of money income, the price level of other goods, the nature of the good, the existence of substitutes, and the tastes of consumers. A change in any one of these variables will cause a shift in the demand curve. If the money income

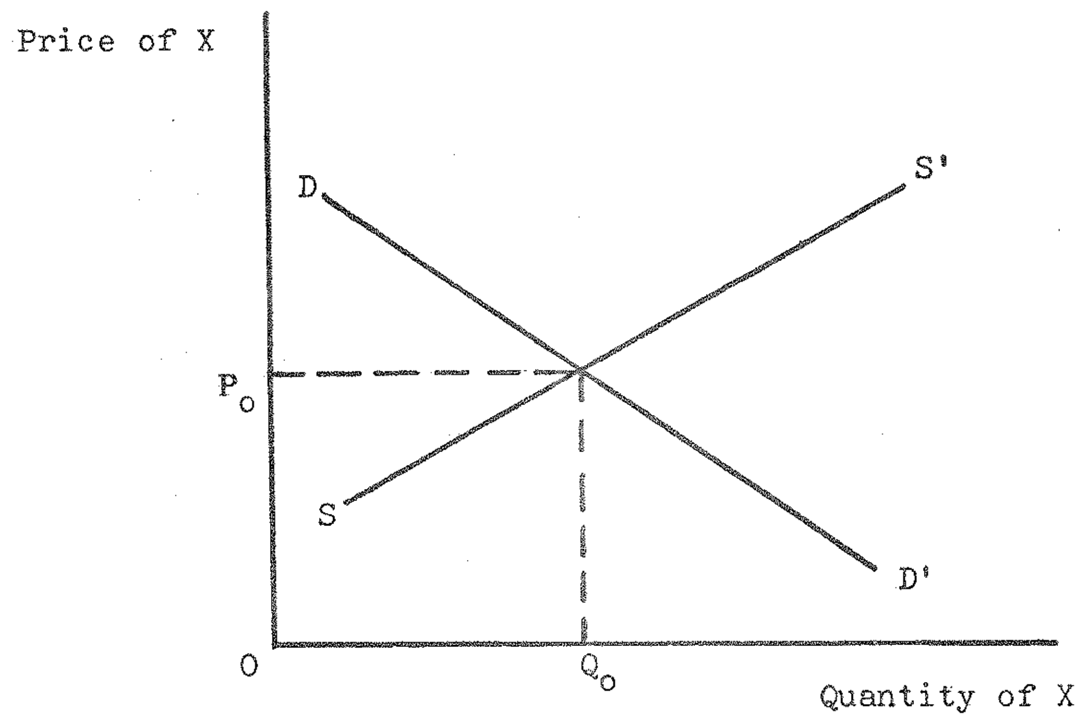

Figure 2.1. Determination of Equilibrium under Perfect Competition.

of consumers would increase, for example, the demand curve would be expected to shift upward and to the right, say to D_1D_1' in Figure 2.2. The equilibrium quantity purchased would now increase to Q_1 at a price of P_1, assuming all other variables were held constant. A decrease in income would have the opposite effect.[1]

The supply curve may also shift. A change in the input cost necessary to produce the good, a tax change affecting

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[1] This is true in the case of a "normal good". For a detailed discussion of normal goods, see Mansfield, Edwin, Microeconomics, W.W. Norton and Co., Inc., 1970.

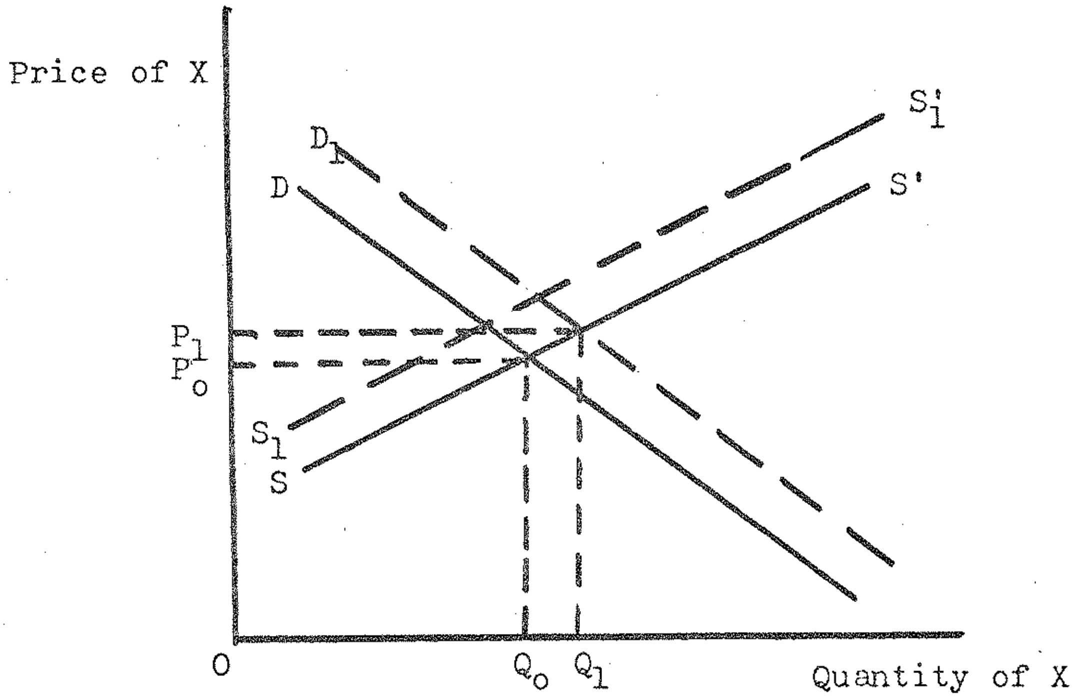

Figure 2.2. Shifting the Demand and Supply Curves.

the good, a technological change, or some other factor affecting the profitability of the good may cause the supply curve to shift. An increase in the cost to produce a good, for example, would normally be an incentive to decrease the quantity supplied causing the supply curve to shift upward and to the left, say to S_1S_1', again changing the equilibrium price and quantity levels. It is important to distinguish between a shift in the supply and demand curves, as illustrated above, and a movement along the curves.

The slope of the supply and demand curves are obviously dependent on the nature of the good being considered. In this study, the selling price of a number of residences located in various areas of a city will be examined. The supply, or number, of residences in a residential area is fixed in the short run. The supply curve, then, is perfectly inelastic, or or vertical. Hence, a price increase or decrease will have no effect on the number of residences available in a given area. The situation is illustrated in Figure 2.3 below.

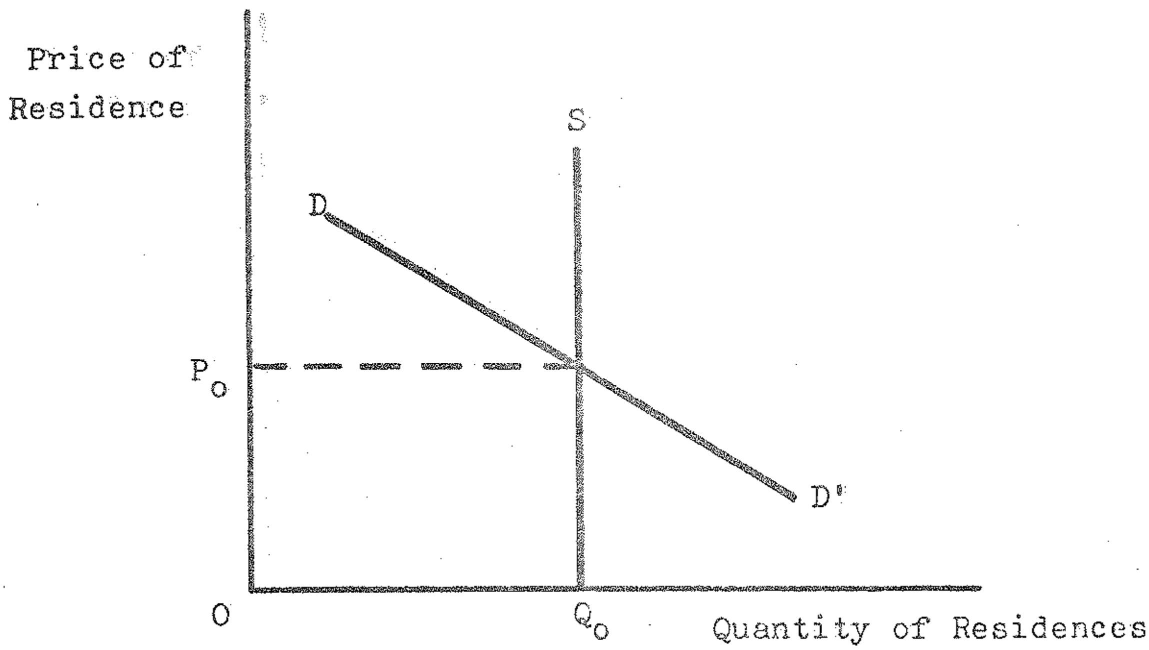

Figure 2.3. Hypothetical Supply and Demand Curves for Residential Housing.

The demand curve for residential housing would be expected to have somewhat of a negative slope as shown above, although knowledge of the exact elasticity is not required for this analysis. The reason for the expected negative slope is that it would be expected that homes would become less desirable as they become more crowded into a given area.

One objective of this study was to determine the amount of change in residential property value that would result from the installation of an adequate storm drainage system in flood-prone residential areas. The installation of adequate storm drainage and the subsequent elimination of the flooding hazard will, in effect, improve the quality of the residential property involved. A change in the quality of a residence will, theoretically, shift the demand curve for that residence. This study will measure the extent of the demand curve shift as reflected in sale value.

Suppose the original demand curve for property located in flood-prone residential areas is DD' in Figure 2.4. If the quality of the property is improved, i.e., if the area is provided adequate drainage, an upward shift in the demand curve, say to D_1D_1', will be expected. Hence, it is expected that the property will be more valuable to its owners if the drainage problem is corrected.

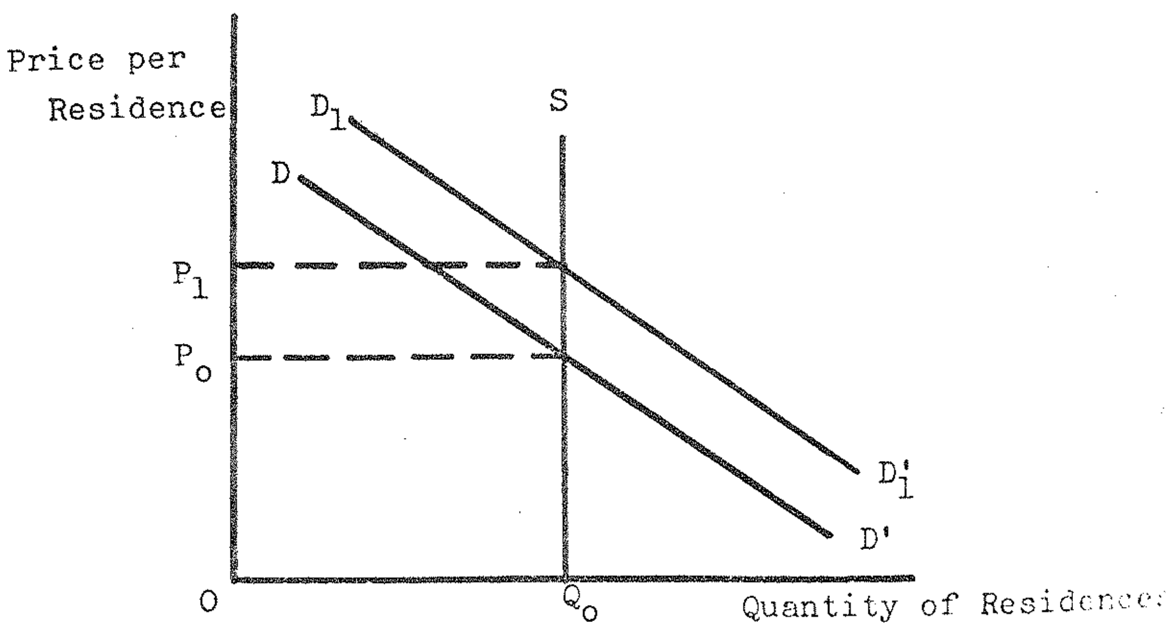

Figure 2.4. Hypothesized Effect of a Quality Change on the Demand for Residential Housing.

Before the drainage problem is corrected, residences in the problem areas will have an average price of P_o. After the drainage system is installed and the flooding problem is eliminated, the demand curve will shift upward increasing the sale price to P_1. The model used to estimate the magnitude of the demand shift is examined closely later in this chapter.

The Concept of Economic Rent[2]

In recent years, an increasing number of economists have undertaken studies based on the concept of economic surplus. As Bhagwati[3] has stressed, the measurement of losses and gains from changes in policy has resulted from pressure on economists to provide such measures.

The most useful definition of economic rent has been the topic for exhaustive controversy.[4] Classically defined, economic rent is the payment over and above the minimum

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2 Economic rent is also commonly referred to as producers' surplus. Since the rent, or surplus, relevant to this analysis accrues to the owner of the residence and not to the producer, the term producers' surplus may be somewhat misleading. Therefore, the term economic rent will be used in this analysis.

3 Bhagwati, Jagdish, "The Pure Theory of International Trade: A Survey", American Economic Association and Royal Economic Society, Survey of Economic Theory, Vol. 2 (New York, 1965).

4 For a discussion on the most appropriate definition of economic rent, see Currie, J., T. Murphy and A. Schmitz, "The Concept of Economic Surplus and Its Use in Economic Analysis", The Economic Journal, December, 1971, pp. 741-799.

amount necessary to attract that input into its present use.[5] Graphically, this is equal to the area above the supply curve but below the price line.

For the case of residential housing, it has been assumed that the supply curve, for the time span relevant to this analysis, is fixed, or inelastic. In the case of any commodity with an inelastic supply at all prices, the whole payment for the commodity is economic rent, since the commodity would be supplied even if nothing were paid for it.[6]

When the supply is fixed, as shown in Figure 2.5, the price of the residence, i.e., the economic rent, is determined completely by the demand curve. It is clear that the shape of the demand curve will have no effect on the amount of economic rent; only its point of intersection with the supply line is important. If, for example, the demand curve is DD' or D_oD_o', the economic rent is OP_oEQ_o; if the demand curve is D_1D_1' or D_2D_2', the economic rent is $OP_1E'Q_o$. Thus, a shift in the demand curve, regardless of its shape, directly affects the amount of economic rent accruing to the owner. In this case, the demand curve shift increased economic rent by an amount equal to the area $P_oP_1E'E$. This concept will be fundamental later in the analysis.

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5 See Mansfield, op. cit., p. 352.

6 Boulding, K. E., "The Concept of Economic Surplus", American Economic Review, Vol. XXXV, December, 1945, p. 83.

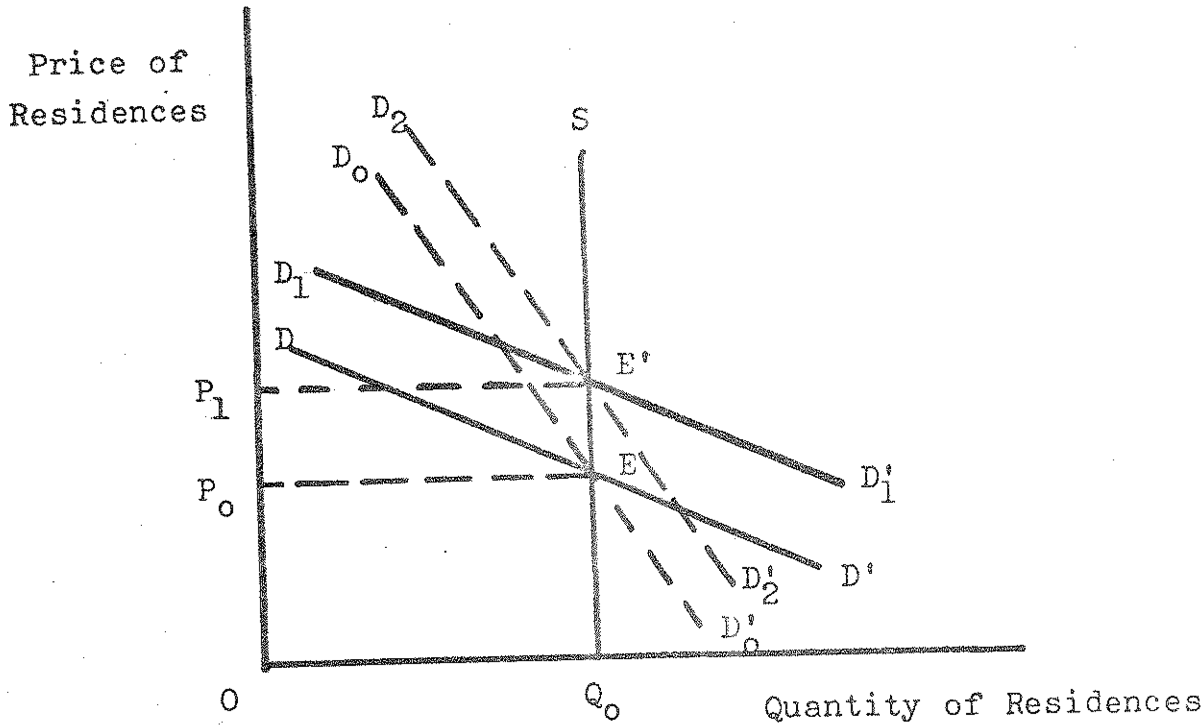

Figure 2.5 Effect of Demand Curve Shift and Slope Change on Economic Rent.

Linear Regression Analysis

A linear regression model will be used in this study to compare properties, thereby estimating the damage function as reflected in sale price. This technique permits the comparison of residences that are not strictly comparable in factors other than flood risk. The increased comparability is accomplished in the regression model by weighting each of the non-flood factors to reflect their importance in the explanation of property values and by using a sample sufficiently large to provide statistical reliability. These factors will then account for the variation in selling price that is not a function of drainage adequacy.

A very similar approach was used by Struyk[7] to estimate the effect of flood risk on the sale value of agricultural land. Struyk's model "indicated that a significant differential associated with flood risk exists between each of the flood-free areas and the flood-prone area and that the differential, on the average, is approximately $25 per acre."[8]

Nourse[9] used a linear regression model to estimate the benefits of air pollution abatement. The model was used to detect the decrease in sale value of residential property resulting from being located in areas of severe air pollution. His study indicated that property values decreased by an average of approximately $1000 per residence in the areas of high air pollution, *ceteris paribus*.

The impact of stream pollution abatement was studied by Barrager[10] using the technique of linear regression analysis. Barrager found that property values increased as the water

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7 Struyk, Raymond J., "Flood Risk and Agricultural Land Values: A Test", *Water Resources Research*, Vol. 7, August, 1971.

8 *Ibid.*, p.

9 Nourse, Hugh O., "The Effect of Air Pollution on House Values", *Land Economics*, May, 1967.

10 Barrager, Stephen M., "The Impact of Water Resource Quality Changes on Surrounding Property Values", *Water Resources Bulletin*, Vol. 10, No. 4, August, 1974.

pollution decreased. The amount of the increase was directly related to the distance the property was located from the stream.

The regression model developed for this study will be used to measure that portion of residential property value variation that is a result of drainage adequacy. This value will be directly interpreted as the benefit that property owners in flood-prone areas would achieve as a result of the installation of an adequate storm drainage system.

The population regression model may be stated as:

$$Y = B_o + B_1X_1 + B_2X_2 + \ldots + B_kX_k + E$$

where Y is the dependent variable, the B's are the regression coefficients, the X's are the independent, or explanatory variables, and E represents an unknown error term. The purpose of the regression model is to estimate the values of the regression coefficients which minimize the squared deviations, or residuals, of the dependent variable from the estimated value. The estimated regression model is:

$$\hat{Y} = b_o + b_1X_1 + b_2X_2 + \ldots + b_kX_k + e$$

where $\hat{Y}$ is the estimated value of the dependent variable and the b's are estimates of the regression coefficients.

Assumptions of Classical Least Squares Regression Analysis[11]

The Classical Least Squares Regression model is based on the following assumptions:

1. $Y = XB + E$: that each observed Y is a linear function of the disturbance E_j. This means that the linear specification of the model is correct.
2. $E(e) = 0$: that each error, or disturbance, is considered a random variable with an expectation of zero.
3. $E(ee') = O^2I$: that each of the error terms has the same expected square, and this expectation is a variance, or $E(e_1{}^2) = E(e_2{}^2) = \ldots = E(e_n{}^2) = O^2$. Thus, it is assumed that all e_i have the same variance.
4. X is an n x (1 + k) matrix which is fixed in repeated sampling: that the regressors are non-stochastic (fixed), implying X and e are independent.
5. Rank of $X = k + k \leq n$, or X is of full column rank, meaning that there is no exact linear relation among the regressors, or independent variables.

   where: K is the number of independent variables,

   Y is an n x 1 matrix

   X is an n x (k + 1)

   e is an n x 1, and

   ee' is an n x n matrix.

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11 Kehrberg, Earl W., "Agricultural Economics 601 Summary Notes", September, 1974.

The linear regression model is the simplest one. It assumes that a change in any independent variable will contribute a constant amount to the dependent variable, in this case sale price, regardless of the other variables present. Thus, using this functional form, it is assumed that a third bathroom will add the same amount to the sale price as the first and the second. Obviously, in the extreme case, this assumption will not hold, i.e. one would not expect a fifth bathroom to add the same amount to sales price as the first and second. However, the reasoning for using the linear model is that the data range is sufficiently narrow in this analysis that the value of having a declining marginal term, which is provided by a non-linear functional form, will not significantly add to the predictive power of the model. This assumption has been substantiated by the results of work done by Penn and Irwin[12] and Trippi.[13] Since extreme values in the variates were eliminated in this analysis and because the sample population was relatively homogenous in nature, it was decided that the linear form was appropriate for this study.

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12 Penn J. B., and George D. Irwin, "Using Multiple Listing Service Data to Analyze Determinants of Residential Property Values", Journal of Northeast Agricultural Economics Council, Vol. 1, No. 1, Summer, 1972.

13 Trippi, Robert R., " A Comparison of Linear and Nonlinear Models of Residential Real Property Value", The Appraisal Journal, October, 1974,

Measuring Goodness of Fit

After the regression coefficients of equations have been estimated, the next step is to evaluate the "goodness of fit" of the estimated equation. The goodness of fit measures provide information about the precision and the predictive capabilities of the estimated regression equation.

One criterion that is commonly used to measure the adequacy of a regression model is the "coefficient of multiple determination", or the R^2 value. The formula for the R^2 of the regression equation adjusted for degrees of freedom is:[14]

$$\bar{R}^2 = 1 - \left(1 - \frac{\Sigma(Y-\bar{Y})^2 - \Sigma(Y-\hat{Y})^2}{\Sigma(Y-\bar{Y})^2}\right)\left(\frac{n-1}{n-k-1}\right)$$

where $(Y-\bar{Y})^2$ and $(Y-\hat{Y})^2$ are variations of the dependent variable and the residuals, respectively. Hence, the coefficient of multiple determination measures the proportion of variance in the dependent variable that is explained by variation in the independent variables. R^2 x 100 can be interpreted as the percentage of variation in the dependent variable that is explained by the regression model. If the relationship between explained and total variance were perfect, the value of R^2 would be unity. The closer the value of R^2 is to unity, the better the fit.

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[14] Brown, Ralph J., "On the Selection of the Best Predictive Model in Multiple Regression Analysis", The Appraisal Journal, October, 1974, p. 574.

Another very important measure of goodness of fit is the "standard error" of the estimated regression coefficient. The standard error provides information about the size of the residuals, or errors, generated by the regression model. Since the expected mean of the residual is zero, the standard error can be thought of as the typical size of the residual. Because the residual is the difference between the predicted and the actual value, the standard error is the typical error in prediction. The formula for the standard error of the estimate, adjusted for degrees of freedom is:[15]

$$S_e = \sqrt{\frac{(Y-\hat{Y}^2)}{n-k-1}}$$

The properties of this measure are such that the regression equation with the smallest standard error will also have the highest R^2.

A technique commonly used to measure the statistical significance of individual variables and the total equation is the F-test. By referring to a table of F values, the probability that the actual population regression coefficient differs from the estimated coefficient by more than a given number of standard errors can be determined. The formula

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[15] Ibid., p. 574.

for the F-test is:

$$F = \frac{R^2}{1-R^2}$$

The F-test must be used with caution. When multicollinearity exists between the independent variables, the effect is to increase the size of the standard errors of the estimated coefficients so that the coefficients individually are not significant, but jointly may be highly significant. Thus, using the F-test as sole guide could result in the inclusion of variables that should not be included.

Relation of Model to Theory

Linear regression analysis is an appropriate technique to use for estimating the monetary value that property-purchasers attach to the existence of adequate storm drainage. The regression model will actually estimate one point on each of two different demand curves; one point on the demand curve for residences with adequate drainage, and one point on the demand curve of residences with inadequate drainage. The difference between the points estimated by the model will equal the average estimated differential in sale value of two residences, identical except for drainage adequacy. The estimated differential will serve as a measure of the shift occurring in the demand curve for residences located in flood-prone areas as a consequence of installing adequate storm drainage facilities. This value may be multiplied by the total number of residences in an area whose drainage problems would be eliminated by a given drainage relief proposal in order to provide an estimate of the total homeowner benefits that would result from the implementation of that particular proposal.

Since the properties included in this analysis were classified as being located in either an adequately or an inadequately drained area, only one estimate was made of the homeowners expected damage estimate. Therefore, it must be remembered that this estimated differential is the <u>average</u> value of the discount for all those residences situated in inadequately drained areas. Preferably, the problem areas would have been separated as to the degree of flooding severity. This would enable the estimation and plotting of a continuous curve indicating the change in the value of the discount, and thus the potential benefit, as the severity of the drainage problem changed. This procedure was attempted in this study, but was not successful due to the difficulty in separating residences by the seriousness of the drainage problem.

CHAPTER III

THE CASE STUDY AREA

This chapter includes two general sections. The first section is a description of the case study area, including the location, the topography, and the soil types involved. The second section contains a discussion of the present storm drainage system in the study area.

The Case Study Area[1]

The City of Anderson, located in the east-central part of Indiana, was chosen as the case study area. Anderson is the largest city in and the county seat of Madison County. Anderson is located 35 miles northeast of the state capitol, Indianapolis; 18 miles southwest of Muncie, and about 28 miles south of Marion. Figure 3.1 indicates the location of Anderson.

Throughout its existence, Anderson has continuously grown in size and population, steadily absorbing rural land to provide additional space for residential, commercial, and industrial development. In 1960, Anderson consisted of 9.5 square miles. In 1962, an area of 27 square miles was annexed

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[1] For additional information see U.S.D.A.-S.C.S., "Soil Survey, Madison County, Indiana", Issued March, 1967.

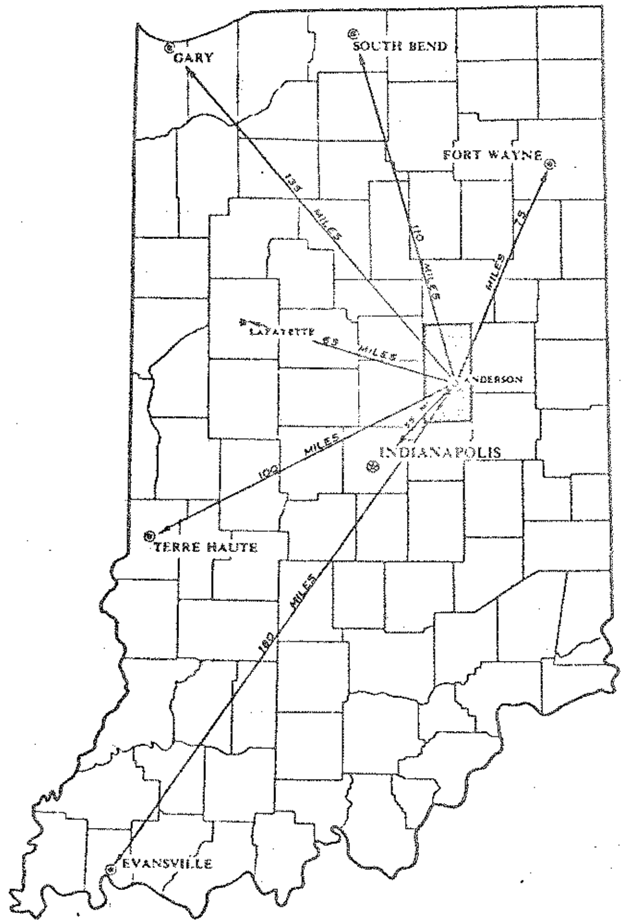

Figure 3.1. The Location of Anderson, Indiana.

bringing the total area included in the city limits to 36.5 square miles. This annexation, which increased the City's population by 18,000, together with the natural population growth, has brought the present population of Anderson to over 70,000. This general population trend is expected to continue, thus requiring additional land for urban development.

Climate

The climate of Anderson is continental. The temperature varies widely from summer to winter months with January and February being the coldest, and July and August being the warmest months. The mean annual temperature is about 55°F.

Precipitation is fairly consistent throughout all seasons with no one month of the year having an average of less than two inches of rainfall. Precipitation is least in winter. The most rainfall comes in the form of thunderstorms in late spring and early summer. There are an average of seven thunderstorms a month during the summer months. Average total precipitation in Anderson is 38 inches; with one year in ten having less than 30 inches or more than 46 inches.

Topography

Madison County is situated on the Tipton Till Plain which occupies most of central Indiana. The surface of this area is that of a relatively level glacial till plain broken only by the post-Wisconsin river and stream systems. The nearly level and gently undulating till plain found at Anderson exhibits the drainage inadequacies found throughout the county. Anderson depends primarily on the White River and its tributaries for storm drainage. However, the natural development of drainage features has been incomplete. Approximately 80% of the land surface in Anderson has a relief of 2% or less. Hence, man has been forced to develop artificial drainage systems, such as drainage ditches and tile drains to supplement the natural drainage system. Although artificial drainage has resulted in substantial improvement, the land surface is still smooth, ungullied, and poorly drained in many areas of the City.

There are twelve major drainage basins serving the City of Anderson. The locational outline of each is shown in Figure 3.2. Each basin is designated in accordance with the name of the principal watercourse serving each of the respective basins. Also shown are major subdrainage boundary lines, watercourses, and drainage pathways. The drainage pathways, indicated by a series of arrows, include open ditches, tile drains, and naturally formed drainage courses.

Soil Characteristics

The properties of the soils found in Anderson tend to further aggravate the drainage problem that already exists as a result of topographical characteristics. Table 3.1 summarizes the major soil series' found in Anderson, the approximate percentage of each, the permeability of each, and the limitations of each which are relevant to the problem under study.

Clearly, a large percentage of the soils listed in Table 3.1, which are now occupied by residential housing, do not exhibit characteristics favorable for that use. Adding to the planning problem is the fact that the poorly-drained Crosby, Brookston, Mahalasville, and Ross soil series' are found predominantly in the newer residential areas of the City while the well-drained Fox soils are found almost exclusively in the central sections. Hence, those soils exhibiting the most serious limitations with regard to residential development tend to be found in the newer residential

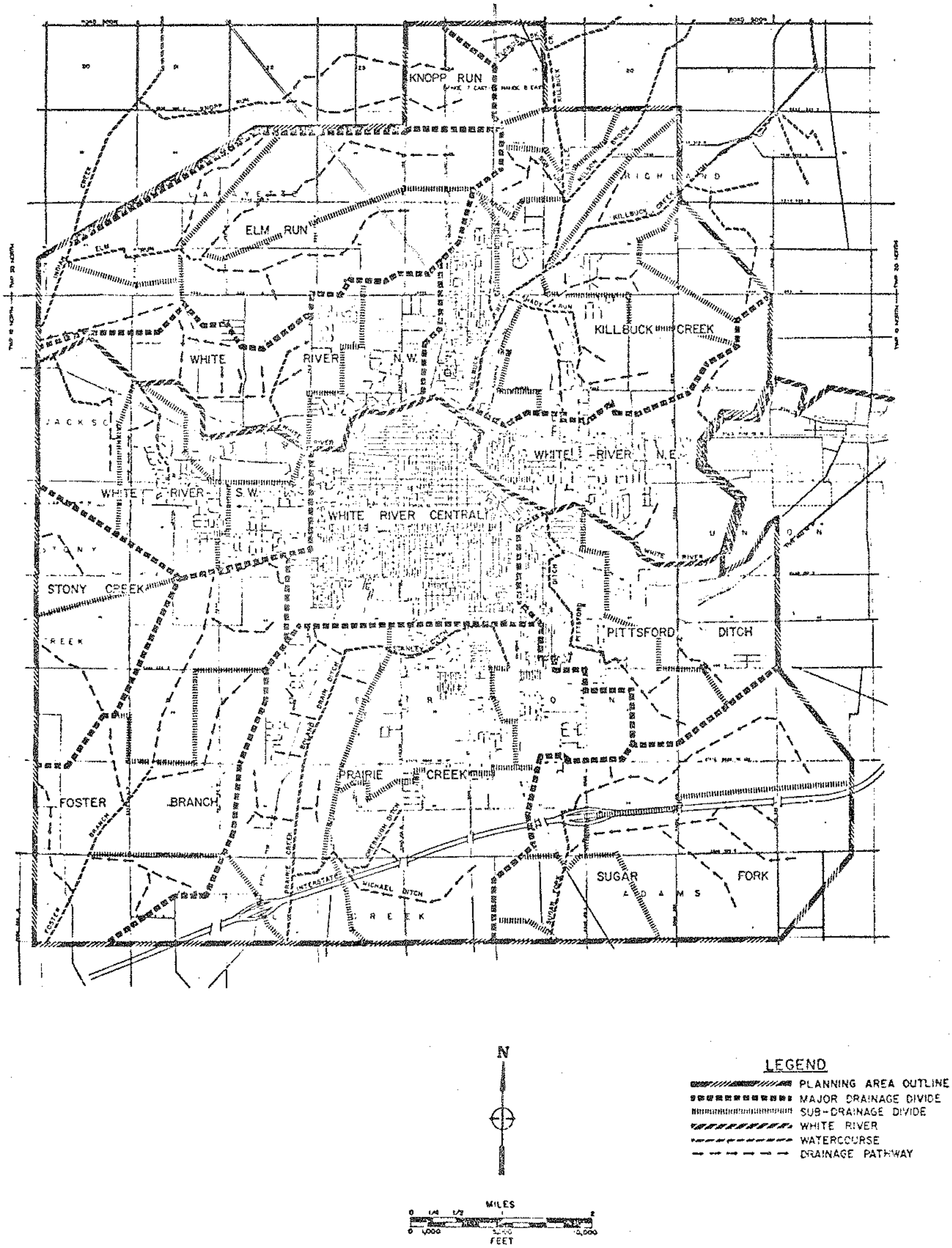

Figure 3.2. Major Drainage Features in Anderson, Indiana.

Table 3.1. Major Soil Series and Characteristics of Soils Found in Anderson, Indiana.

Soil Series[1]	Approx. Percentage	Depth (inches)	Permeability (inches/hr.)	Soil Limitations for - Disposal Fields for Septic Tanks	Soil Limitations for - Building Sites
Crosby	35%	0-10 10-34 34-42	0.8-2.5 0.2-0.8 0.8-2.5	Severe: seasonably high water table	Severe: seasonably table
Fox	25%	0-12 12-36 36-44	0.8-2.5 0.2-2.5 10+	Slight to Moderate: permeability normally good but may be slow in substratum of some Fox soils	None normally: subsoil fair to good; well-drained
Brookston	10%	0-15 15-49 49-59	0.2-0.8 0.2-0.8 0.2-0.8	Very severe: high water table; periodic flooding and ponding	Severe: high water table; periodic flooding and ponding
Miami	8%	0-10 10-26 26-36	0.8-2.5 0.2-0.8 0.2-0.8	Slight to moderate	Slight: erosion control practices necessary on slopes
Kokomo	6%	0-21 21-49 49-56	0.2-0.8 0.05-0.8 0.8-2.5	Very severe: high water table; periodic flooding and ponding	Very severe: high water table; periodic flooding and ponding
Mahalasville	6%	0-13 13-33	0.2-0.8 0.2-0.8	Severe to very severe depending on type of substratum	Severe to very severe; poor drainage; high water table; periodic flooding and ponding.

[1] Those soils occupying less than 5% of the total area were not included in the table.

areas and in the areas now being developed. It is in these areas where the least amount of drainage services have been provided and where the bulk of drainage related problems have been experienced.

<u>The Present Storm Drainage System</u>

Nearly all of the urbanized areas of the City existing before the 1962 annexation are served by combined sewers. Combined sewers are intended to convey domestic and industrial wastes as well as storm runoff from streets, roofs, yards, etc. In many cases, the combined sewers are badly overburdened and in need of relief.

The need for storm drainage relief in many areas of Anderson has been apparent for some time. The urgency for relief, however, becomes increasingly acute as areas become more fully developed and more densely populated. Also, as the size of the City increases, more formerly rural areas are developed for residential use, often without the provision of an adequate storm drainage system.

The failure to provide adequate storm drainage facilities to flood-prone areas has resulted in various types of flood-related damages. Perhaps the most dramatic form of damages are those manifested in the form of real property damages, including damages to the house and to the yard. These are not the only damages that result from urban flooding, however. Additional damages may be incurred as a result of inconvenience to detoured motorists, damage to city streets, and from the disruption of normal business activity. Furthermore, public health officials are concerned about hazards to health created by possible contamination of private water supplies due to the disruption of private septic tank systems. Although public water and sanitary sewer systems continue to be extended, it is not likely that private water supplies or private disposal systems will ever be completely eliminated in the City.

The causes for the inadequate provision of storm drainage services in the past and the reasons for the continuing urbanization of flood-prone areas are somewhat complex. The following factors are thought to be largely responsible, however:[2]

(1) the general lack of understanding concerning the effects of urbanization on the amount of storm runoff generated and the subsequent drainage problems involved.

(2) a tendency for some profit oriented land developers to develop flood-prone areas without providing adequate storm drainage facilities.

(3) ineffective control over the location of new developments through zoning ordinances, etc.

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[2] Philip L. Schnelker, Inc., Master Plan for Storm Drainage-Fort Wayne-New Haven-Allen County Metropolitan Area, April, 1972.

Clearly, if public agencies effectively controlled land use in flood-prone areas, the first two factors would be of little consequence, i.e. it would be less important for people to fully understand the effects of urbanization on storm drainage needs and it would not be possible for developers to develop land in areas not suitable for residential housing. If development was allowed in these areas, city ordinances could require developers to install adequate storm and sanitary sewer services.

Once a developed area is plagued by inadequate storm drainage, it is important for planners to have as much information available as possible in order to properly determine what steps, if any, should be taken to correct the problem. An estimation of what benefits would result and what costs would be incurred is extremely useful information when evaluating a drainage proposal. The methodology used and the estimates made of the benefits and the costs is presented in the following chapter.

CHAPTER IV

DATA SOURCES AND EMPIRICAL ANALYSIS

This chapter is divided into four major sections. The first section contains a brief description of the data sources utilized in the benefit analysis. The second section is a discussion of the criteria used to select the sample of residences used in the benefit analysis from the broad range of data available. The third section presents the empirical models formulated for use in the benefit estimation. It includes the computational results of each model and an interpretation of the results. The fourth section involves the calculation of the costs necessary to provide adequate storm drainage and includes a comparison of the estimated benefits with the costs. The methodology used in this analysis is applicable for use in evaluating a wide range of public project proposals involving various problem settings that are continually faced by city planners and administrators.

Data Sources for the Benefit Analysis

The basic data used for the benefit analysis are residential unit transfers which occurred in the City of Anderson during the period from August, 1972 through September, 1974. Henry County Multiple Listing Service data was used to obtain the necessary sale and property information for each transfer. The information listed on multiple listing service (MLS) cards is very detailed, including the necessary physical and locational characteristics that affect property value. In addition, a photo of each sale listed is included on the MLS card. This allows the detection of relevant locational and physical characteristics such as general maintenance, scenery, existence of trees and shrubs, etc., which are not included as listed information on the MLS card, but which may significantly influence the sale value. Another important factor is that MLS data is generally easily accessible, although not public information, and can be prepared for analytical purposes relatively easily. Penn and Irwin[1] and Dilmore[2] used MLS data in their regression analyses and found the information provided to be quite satisfactory. A sample of a MLS card is shown in Figure 4.1.

One limitation of using MLS data is that transactions accomplished by private sales are omitted. It is possible that accuracy in the model could be improved by the inclusion of private sales, however, since there is an obvious limitation on the absolute accuracy of sales data in the first place, this restriction of MLS data was not considered to

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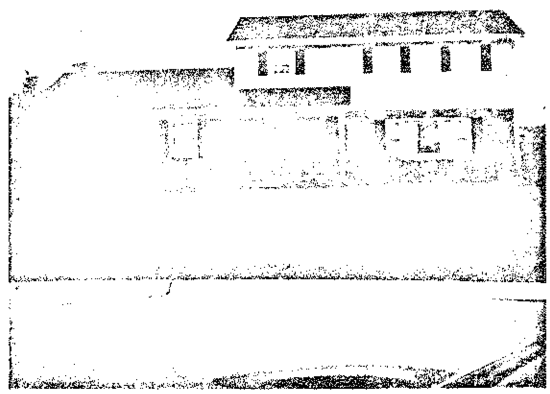
[1] Penn and Irwin, op. cit.

[2] Dilmore, Gene, "Appraising Houses", The Real Estate Appraiser, July-August, 1974.



Price	Address	Rms	BR.	Baths	Style	MLS No.
$40000		7	4	2	Ranch	1241

Realtor		Phone	Code No
Construction Brick		Legal Description	
Age 6	Sq. Ft. 1850	Lot Size 100x160	Possession Immediate

Room	Size	Floor	Cabinets yes		No. Ft.	Dish W. yes
LR	14x18	carpet	Disposal yes	Fan no	Oven yes	Refrig. yes
DR	12x18	carpet	Air yes	Units	Attic Fan no	Awnings no
FR			Storm yes	Fence no	Intcom. no	Walls
K	10x14	tile	Shrub yes	Garage yes	Elec. Door no	W. Soft. no
BR	8x12	carpet	TV Ant. no	W. Heater yes	Water yes	Sewer city
BR	8x12	carpet	220 V yes	Gas no	Washer no	Dryer no
BR	8x12	carpet	Patio no	Trees yes	Heat elec.	Basement no
BR	12x14	carpet	Grd. Schl. Franklin		Jr. Hi. Riley	Hi. Schl. North
Bath	8x10	tile	Mort. Bal.		Favor	Mo. Pay.
Bath	8x10	tile	Assess		Improv.	Tax W/X
Car.	20x24		Occupant		Phone	N/X
Out Bldg.	no		Other Features fireplace, cable TV			
REMARKS						

Figure 4.1. Sample of a Multiple Listing Service Card.

be a major limitation.[3] It is assumed, then, that the sales listed with the MLS are adequately representative of sales in Anderson to allow for a representative sample.

Selection of Sales

Obviously, a wide range of homes, in terms of physical characteristics, will be found in any city. Each home will have many characteristics in common with all other homes. These common characteristics, however, can be expected to affect sale value differently for different styles and ages of homes. An additional bedroom in an older two-story house, for example, would be expected to contribute less to sale value than would an additional bedroom in a modern ranch-style house. The inclusion of both types of homes in the analysis, then, would result in an inaccurate estimate of the contribution to sale value made by an additional bedroom in either of the homes.

This analysis was concerned only with a well defined set of homes located in Anderson's residential areas. The residences included in the sample were restricted to single-family residences located in strictly middle-income, white neighborhoods of the City. Appraisers warned that severe distortions in sales price occur in racially mixed neighborhoods. In addition, only ranch-style homes built within the last 15 years were sampled. Although these restrictions may

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[3] Ibid., p. 23.

appear to be quite severe, a relatively small number of those homes located in the residential areas did not meet these criteria.

Theoretically, characteristics such as racial mixture and house style could be included as variables and thus be accounted for in the regression model. However, it became apparent that only a small number of residences in the suburban areas would exhibit a racial mixture or a house style other than ranch. Therefore, including these few residences would only result in unreliable estimates of the style and racial variables and introduce additional error into the model.

It was assumed that the particular residential section of the City in which a residence is located does not significantly affect its sales value. This is reasonable to assume, given the previous housing criteria, since Anderson is a relatively small city; all parts of the City being easily accessible within a few minutes drive. It was further assumed that all schools serving the suburban areas are equally desirable and that the school district in which a residence is located does not significantly affect its sale value. Similar assumptions were made for a residence's location with respect to transportation routes, industrial areas, parks, etc.

With the above criteria in mind, information was obtained for 171 residential unit transfers in Anderson that had been listed with the Henry County MLS. Of these, 40 were located in flood-prone areas; the remainder were considered to be adequately drained. The flood-prone areas were identified by an appraiser in Anderson, who was knowledgeable of and had experience in, the various residential areas. This was followed by a personal inspection of each of the properties located in the designated problem areas to verify whether each property was indeed experiencing damages as a result of inadequate storm drainage. The 40 residences identified as being located in flood-prone areas are considered to be representative of those residences in Anderson that are experiencing storm drainage problems.

Formulation of the Model

The linear regression model used in this analysis compared the sale value of residential properties in Anderson to determine how sale value was affected as location with respect to drainage adequacy changed. This requires adjusting for all other property characteristics so that only the change in value due to a locational change is measured by the locational variable.

It is necessary at this point to determine what residential property characteristics should be included as independent, or explanatory, variables in the model. A useful rule of thumb is to include all those variables that are likely to be at least as important as the variable of primary interest, in this case the locational variable. It is then reasonably likely that the primary variable will not prove to be significant only because it happened to be correlated with some more important variable that was left out of the model.[5]

It is very important that the set of explanatory variables be selected in such a way that the problem of high intercorrelation among the explanatory variables is avoided. When an intercorrelation problem does exist, the estimated coefficients will be inefficient, or inaccurate, and the reliability of the model will be questionable. Evidently, this problem was not considered by Penn and Irwin.[6] Their regression model included the variables house size, number of bedrooms, number of bathrooms, and total number of rooms. Obviously, high intercorrelation will exist between these variables since each is measuring much the same characteristic, i.e. house size. The expectation of high intercorrelation and thus inefficient estimates in their model is borne out by the fact that the values of the regression coefficients estimated by Penn and Irwin's model varied

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5 Ridker, Ronald G. and John A. Henning, "The Determinants of Residential Property Values with Special Reference to Air Pollution", The Review of Economics and Statistics, May, 1967, p. 248.

6 Penn and Irwin, op. cit.

widely from those estimated by other regression models designed for similar purposes.[7]

On the basis of the above considerations, a set of variables was determined and a model was constructed for use in this study. This model will be referred to as Model I. The form of the model is as follow:

$$PR = b_o + b_1 DA + b_2 BS + b_3 BA + b_4 WT + b_5 AI + b_6 FP + b_7 AG$$
$$b_8 SD + b_9 LO + b_{10} EX + b_{11} GA + b_{12} QU + b_{13} SZ + e$$

Definition of variables:

PR = sale price of property

DA = date of sale in months before August, 1972

BS = existence of a basement

BA = number of bathrooms

WT = existence of a drainage problem

AI = existence of central air-conditioning

FP = existence of a fireplace

AG = age of house in years

SD = siding, or construction, of house (brick or frame)

LO = desirability of lot (rating of 1 to 3: avg. = 2)

EX = extras included in the sale (rating, same as LO)

GA = number of garage spaces

QU = quality of home (rating, same as LO and EX)

SZ = size of house in square feet of living area

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7 For example, the value of the variable measuring house size was \$2.73/sq. ft. in Penn and Irwin's study compared to values varying between \$8 and \$10 for similar models reviewed.

The nature of some of the explanatory variables required their inclusion as dummy, or zero-one, variables. The dummy variable is a simple and useful method of introducing into a regression analysis information contained in variables that is not conventionally measured on a numerical scale.[8] Fireplace, for example, was included as a one if the house had a fireplace and a zero if it did not. The estimated regression coefficient for fireplace, then, is the estimated amount that a fireplace will add to the sale value of a residence. Of the 13 explanatory variables included in Model I, five were included as dummy variables. The dummy variables in Model I are: basement (BS), air-conditioning (AI), fireplace (FP), siding (SD), and a variable (WT) identifying the existence of a drainage problem.

The remaining eight variables in Model I were included as discrete variables. "A discrete variable is one which can take on only a finite, or denumerable, number of values."[9] The estimated coefficient of a discrete variable can be read directly as the marginal value of an additional unit of that variable, _ceteris paribus_. The discrete variables included in Model I are: date of sale (DA), size of house (SZ), age

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[8] For a detailed discussion on the use of dummy variables, see Suits, David B., "Use Of Dummy Variables in Regression Equations", _Journal of the American Statistical Association_, Vol. 52, No. 280, December, 1957.

[9] Ostle, Bernard, _Statistics in Research_, Revised Second Edition, Iowa State University Press, 1972, p. 30.

of house (AG), number of bathrooms (BA), number of garage spaces (GA), extras (EX), quality (QU), and lot (LO).

The estimated regression equation will provide a direct dollar evaluation of each of the attributes of property value as reflected in sale price. The estimated coefficient of the variable of primary interest to this study, the variable WT, will be read directly as the average amount that home-buyers discount the value of residences that are located in flood-prone residential areas of Anderson. This value may be interpreted as the average benefit that would result from eliminating the drainage problem.

Computational Results

The ordinary least squares estimates of the explanatory variables included in Model I are given below.

$$
\begin{aligned}
Pr = {} & -639.53 + 183.88DA - 633.31BS + 1103.56BA \\
& -1732.53WT + 1109.88AI + 837.41FP - 291.29AG \\
& + 1631.81SD + 89.37LO + 958.27EX + 3204.74GA \\
& + 1656.17QU + 7.87SZ
\end{aligned}
$$

$$R^2 = .795$$

Table 4.1 is a summary table giving the estimated B value, the standard error, the F value, the significance level, the cumulative R^2, and the R^2 change for each independent variable included in Model I.

Table 4.1 Summary Table for Model I-Dependent Variable-
Sale Price.

Variable	B	Std. Error	F Value	Sig.	R^2	R^2 Change
Date(DA)	183.88	31.32	34.47	.000	.035	.035
Basement	-633.31	1591.47	.16	.691	.057	.022
Baths(BA)	1103.56	757.89	2.12	.147	.489	.432
Drainage(WT)	-1732.53	570.71	9.22	.003	.494	.005
Air-Cond.(AI)	1109.89	610.89	3.30	.071	.508	.014
Fireplace(FP)	837.41	543.53	2.37	.125	.517	.009
Age(AG)	-291.29	48.63	35.88	.000	.609	.092
Siding(SD)	1631.81	979.69	2.77	.098	.639	.030
Lot(LO)	89.37	423.92	.04	.833	.650	.011
Extras(EX)	958.27	368.03	6.78	.010	.661	.011
Garage(GA)	3204.74	553.53	33.52	.000	.722	.061
Quality(QU)	1656.17	693.71	5.70	.018	.736	.014
Size(SZ)	7.87	1.17	44.96	.000	.795	.059
Constant	-639.53	1761.10	.13	.717		
		Overall	F - 46.87	.000		

Overall, it appears that Model I is satisfactory in explanatory, indicating that nearly 80% of the variation in sale price is explained by the independent variables included in the model. This R^2 value compares favorably with the R^2 estimates made by other models that were used for similar purposes.

A comparison of each of the regression coefficients with its standard error, together with an examination of the F value, gives an indication of the statistical reliability of the regression coefficient. A statistically reliable coefficient is one with a large F value and a standard error that is small relative to the size of the estimated coefficient. In this case, an F value of about 3.63 is needed for a variable to be significant at the .05 level of significance. Seven of the 13 explanatory variables were significant at this level. The variables BS and LO were the least significant, contributing very little to the explanatory power of the model. Notice that the standard errors are larger than the estimated coefficients themselves for these variables and the F values are extremely low. The variables AI, FP, BA, and SD also were insignificant at the .05 level, however, their significance levels were still fairly high. Since eliminating the variables BS and LO could change the significance of the remaining variables, it was decided that these three variables should be included in the next formulation.

An examination of the signs of the estimated coefficients indicates that all of the variables, with the exception of BS, do have the expected sign. Normally, it would be expected that a basement would make a positive contribution to the sale value of a residence. The reason for the negative sign is very likely that too few houses with basements were included in the sample, and therefore that reliable estimates were not possible. An examination of the sample data verified this suspicion, as only four houses included in the sample did have a basement. These four sales and the BS variable were subsequently eliminated for the next formulation.[10]

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[10] The four houses with basements were located in flood-free areas, therefore inadequate drainage was not the cause of the negative sign.

The non-significance of the LO variable also can be explained by an examination of the sample data. The residential lots included in the sample showed very little variation in size and quality. Therefore, the inclusion of the LO variable was inappropriate in this case and was also eliminated for the next formulation.

The variable of primary importance in this study, WT, was found to be highly significant in Model I. The estimated coefficient for WT indicates that home-buyers discount resi-residences located in flood-prone areas of Anderson by an average of $1732, about 6.8% of the mean selling price.

An examination of the correlation matrix indicates that the variable WT was not closely correlated to any other explanatory variable included in the model.[11] Furthermore, it is believed that no important variable has been excluded from the model that could have caused the WT variable to be significant only because of a high correlation between WT and the excluded variable. This belief is substantiated by the fact that the residences located in flood-prone areas are scattered throughout the residential sections of the City and that a personal inspection found these residences to be comparable in all physical characteristics to those located in well-drained areas. It can be assumed, then, that WT is in fact measuring the sale value discount that is associated with inadequate drainage. The magnitude of WT can be expected

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[11] Refer to Appendix A for the correlation matrix.

to vary somewhat when the insignificant variables LO and BS are eliminated.

Model II

The variables BS and LO were eliminated for the second formulation and those residences with basements were deleted from the sample. The least squares estimates of the explanatory variables included in Model II are given below.

$$\begin{aligned} Pr = & -579.99 + 199.95DA - 297.07AG + 709.19FP \\ & - 1763.41WT + 752.84EX + 1682.68SD + 1194.03AI \\ & + 3213.03GA + 1522.78QU + 7.92SZ + 1457.76BA \end{aligned}$$

$$R^2 = .811$$

Table 4.2 presents the summary table of Model II.

Table 4.2 Summary Table for Model II-Dependent Variable-Sale Price.

Variable	B	Std. Error	F Value	Sig.	R^2	R^2 Change
Date(DA)	199.96	30.04	44.30	.000	.039	.039
Age(AG)	-297.07	46.15	41.44	.000	.262	.223
Fireplace(FP)	709.19	513.55	1.91	.169	.325	.062
Drainage(WT)	-1763.41	542.74	10.56	.001	.342	.017
Extras(EX)	752.84	347.50	4.69	.032	.456	.114
Siding(SD)	1682.68	919.27	3.35	.069	.512	.056
Air-Cond.(AI)	1194.03	580.74	4.23	.041	.514	.002
Garage(GA)	3213.03	525.24	37.42	.000	.649	.135
Quality(QU)	1522.78	659.45	5.33	.022	.693	.044
Size(SZ)	7.92	1.03	58.55	.000	.805	.112
Baths	1457.76	696.53	5.38	.038	.811	.005
Constant	-579.99	1607.35	.13	.719		
		Overall	F - 61.88	.000		

Model II provides a somewhat better fit than did Model I. The elimination of the variables BS and LO has resulted in decreases in the standard errors of all the explanatory variables and a slight increase in the overall R^2 value. In addition, there are now nine of the 11 variables significant at the .05 level. The SD and FP variables, although not significant at the .05 level, are still fairly significant and do add a good deal to the explanatory power of the model. Therefore, they are retained in the model.

The standard error and the F value of the WT variable indicates that this variable is highly significant and that the estimated coefficient is statistically reliable. Again, the correlation matrix indicates no intercorrelation problems for WT and none are expected between WT and any excluded variable. The estimated coefficient for WT, $1763, may be interpreted as the value of the average benefit that would accrue to each residence located in flood-prone residential areas of Anderson if the flooding problem were eliminated. This value is strictly an average value for the residences included in the sample and would be expected to vary somewhat from neighborhood to neighborhood as the severity of the drainage problem changed. It is believed, however, that this damage estimate is representative of the damages that are being experienced in most of the flood-plagued residential areas of Anderson.

The regression coefficients and the explanatory capabilities of Model II compare favorably with other models that have been estimated for use in studies similar to this. Since it is not known how to further increase the precision or explanatory capabilities of this model, the equation estimated by Model II will be used as the final regression equation.

Benefits of Drainage Correction as Measured by Economic Rent

As stated in Chapter II, the supply of homes situated in residential areas can be considered to be fixed. Hence, the economic rent accruing to the owners of these homes is measured purely by the selling price. The price in turn is determined completely by the demand curve.

In this case, the original demand curve for residences situated in flood-prone residential areas is represented by DD' in Figure 4.1. The initial economic rent is represented by the area OAB$\bar{Q}$. The elimination of the flooding hazard results in a change in the desirability, or quality, of the flood-prone residences, thus causing a shift in the demand curve. In this case, the demand curve shifts upward from DD' to D_1D_1' as the flooding hazard is eliminated and the quality of the residence is enhanced. The shift in the demand curve, as estimated by the regression model, results in an increase in the sale value of residences located in flood-prone areas of $1763 on the average. The total economic rent, then, increases from OAB$\bar{Q}$ to OA'B'$\bar{Q}$. Hence, elimination of the

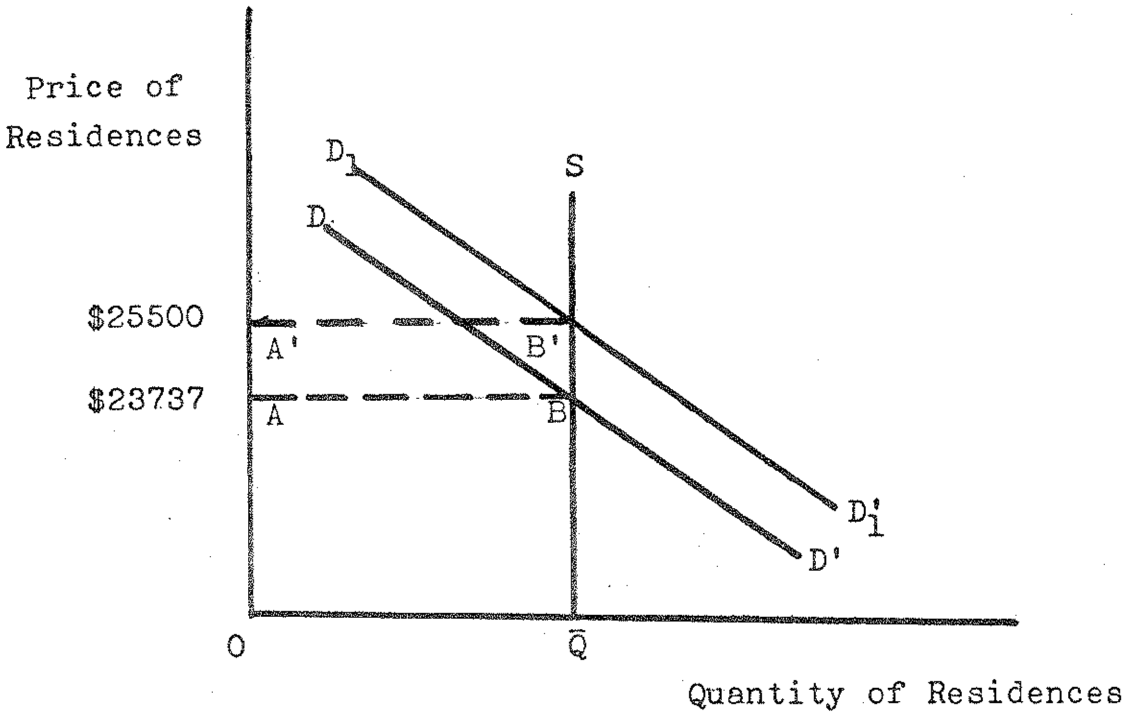

Figure 4.2 The Effect of Adequate Storm Drainage on Economic Rent.

flooding hazard has increased economic rent by the area AA'B'B.

Cost of Providing Adequate Storm Drainage

In order to determine the efficiency of a drainage project, it is necessary to compare the benefits of correcting the drainage problem with the costs of providing it. The cost data used for this study were taken from a storm drainage master plan done for the city of Anderson in 1967.[12] The drainage plan proposed relief sewers for those areas of the

[12] The plan was prepared by Henry B. Steeg and Associates, Inc., City of Anderson, Indiana - A Master Plan for Surface Water Drainage, November, 1967.

City where the combined sewer system was inadequate and, in addition, proposed storm drainage systems for those residential areas where no storm drainage facilities whatsoever existed. Figure 4.3 shows the final drainage proposal made for the City.

Since the benefits of adequate storm drainage were estimated as an average per residence, the costs will be estimated on a per residence basis also. To accomplish this, one of the 12 areas where a drainage system was proposed must be selected as the cost study area. The average cost of that system, per residence served in the area, can then be calculated.

Selection of the Cost Study Area

The area selected for the cost calculation must be carefully chosen. The characteristics of the area should be as similar as possible to the characteristics of the residential areas used in the benefit estimation. This will permit a valid comparison to be made between the benefits of the drainage system and the cost to provide it.

There are several criteria that the chosen area must meet in order for it to be appropriate for use in the cost analysis. The area must be exclusively residential, and consist only of single family residences. Other types of development would change the amount of runoff generated and thus the drainage capacity required. The topographical and soil characteristics of the selected area also must be similar to

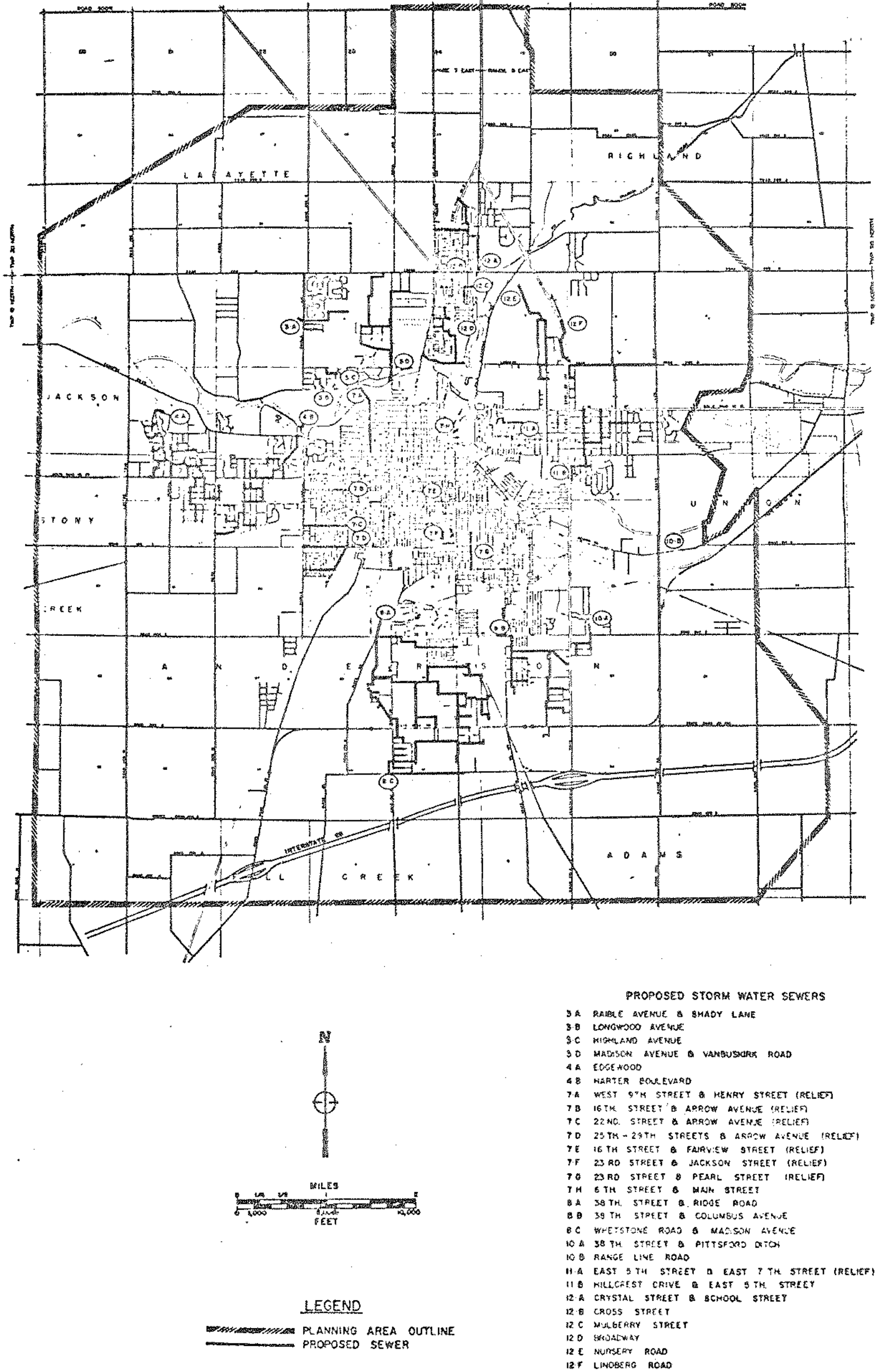

Figure 4.3. Proposed Storm Sewers for Anderson, Indiana.

those in areas used for the benefit analysis since these factors also directly affect the amount of runoff. In addition, the area selected must not be presently served by any existing drainage system. This too would affect the size and thus the cost of the proposed drainage system.[13]

After taking the above criteria into consideration, the area included in the 38th Street and Columbus Avenue storm sewer proposal was selected for purposes of calculating storm drainage system costs. This area is located in the southeastern section of the City and is typical of those outlying areas of Anderson that have recently undergone urbanization. This area is occupied excluseively by single family residences and exhibits no discernable characteristics which would distort the cost estimates. Furthermore, it was found that the costs per residence of installing the drainage system proposed for this area was representative of the costs of proposals made for other residential areas of the City. Figure 4.4 shows the 38th Street and Columbus Avenue storm drainage proposal.

In order to stimate the costs on a per residence basis, it is necessary to determine how many residences this system will serve. The total area available for residential lots

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13 Note that it is not necessary that the area selected be in a flood-prone area; only that it will require a drainage system similar in size and cost to that needed in the flood-prone areas that were used in the benefit analysis.

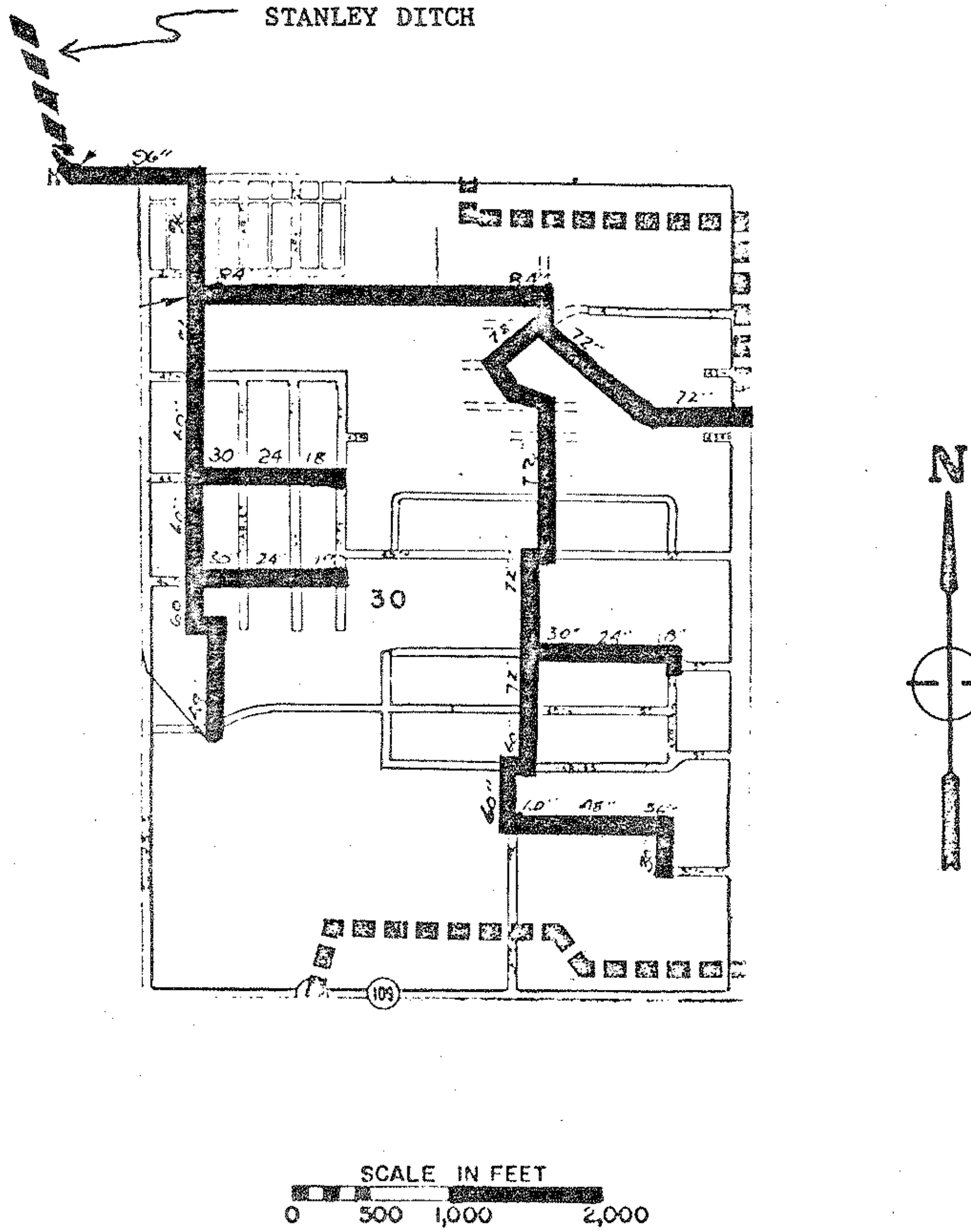

Figure 4.4. The 38th Street and Columbus Avenue Storm Drainage Proposal.

is found by determining the total area served by the system, less the area occupied by streets. The number of residences that will be served can then easily be determined by dividing the total lot area available by the average size of a lot. Finally, the cost per residence is found by dividing the total cost of the drainage system by the number of residences served. Assuming that all the requirements concerning the area selected have been met, this cost figure will be an accurate estimate of the average cost per residence of providing an adequate storm drainage system to the residential areas of Anderson.

The Cost Calculations

The 38th Street and Columbus Avenue storm sewer proposal was designed to serve the area bounded by 38th Street on the north, 53rd Street on the south, SR109 on the east, and Columbus Avenue on the west. This area encompasses approximately 19,950,000 square feet, or about 458 acres.

It was estimated that the streets in this residential area would occupy approximately 17.6% of the total area, or 3,511,200 square feet when fully urbanized.[14] The net area available for residential lots is the difference between the total area and the area occupied by streets, or 16,438,800

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14 Since the streets in this area have not yet been completed, the estimate of 17.6% made by Erickson for a residential area in W. Lafayette was used, Erickson, Stephen P., "Economic and Environmental Impacts of Alternative Methods of Surface Runoff Disposal", unpublished M.S. Thesis, Dept. of Agricultural Economics, Purdue University, 1973, p.30.

square feet. At the time the drainage proposal for this area was made, the area was only partially urbanized. However, it is assumed that the area will become fully developed and that the drainage system was designed to adequately handle the runoff from this area when totally urban residential.

The mean size of the residential lots included in the benefit analysis was 15,100 square feet. It will be assumed that the average size of lots in this particular area is also 15,100 square feet. The total number of lots, or residences, that are served by the drainage system is then found by dividing the total area available for lots, 16,438,800 square feet, by the average size of the lots. Hence, it is estimated that approximately 1089 residences will be located in the area and will be served by the proposed drainage system.

The cost per residence is found by dividing the total project costs by the number of residences served. The estimated costs to install the proposed 38th Street and Columbus Avenue storm sewer system is itemized in Figure 4.5.[15] These estimates were prepared on the basis of contract construction costs for work of a similar nature, at prices quoted in 1967. Notice that no allowance has been made for treatment

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[15] The basic cost data was obtained from a study done by Henry B. Steeg and Associates, Inc., City of Anderson, Indiana - Surface Water Drainage Study - Construction and Project Cost Estimates, October, 1967.

38th Street and Columbus Avenue

1810 L.F. 96" Pipe Sewer @ $108	$195,480
2110 L.F. 84" Pipe Sewer @ $ 90	189,900
4470 L.F. 72" Pipe Sewer @ $ 75	335,250
3360 L.F. 60" Pipe Sewer @ $ 55	184,800
780 L.F. 48" Pipe Sewer @ $ 40	31,200
370 L.F. 36" Pipe Sewer @ $ 30	11,100
1240 L.F. 30" Pipe Sewer @ $ 24	29,760
960 L.F. 24" Pipe Sewer @ $ 18	17,280
910 L.F. 18" Pipe Sewer @ $ 15	13,650
12 Standard Manholes @ $500	6,000
42 Structured Manholes @ $1200	50,400
16800 L.F. Pavement Repair @ $6	100,800
51062 Cu. Yd. Granular Backfill @ $5	255,310
Drainage Structures	54,000
Miscellaneous Construction Contingencies	14,930
TOTAL ESTIMATED CONSTRUCTION COST	$1,489,860
Non-construction Cost	297,972
TOTAL PROJECT COST	$1,787,832

Figure 4.5. Cost Estimate of Providing Storm Drainage to the 38th Street and Columbus Avenue Residential Area after Urbanization.

costs. Since it has been established that storm runoff is an important carrier of pollutants, it may be required that storm runoff be treated before disposal in the future. This would inflate the cost estimate considerably.

Because this area was not completely urbanized at the time these cost estimates were made, some adjustments were necessary for the estimate to accurately reflect the costs of providing the storm drainage system to the area when fully urbanized. The original drainage proposal estimated that approximately 10,200 lineal feet (LF) of pavement repair would be necessary to install the proposed system. However, an examination of the proposal indicates that about 16,800 L.F. of sewer line would be laid in areas now occupied by, or expected to be occupied by streets. Hence, an additional 6600 L.F. of pavement repair was added to the cost estimate to provide a more accurate estimate of the pavement repair required to install the drainage system in the area when fully urbanized.

Because the amount of granular backfill required is determined by the number of lineal feet of street repair, it too was re-estimated. About 3.04 cubic yards of granular backfill is needed for every lineal foot of pavement repair. Therefore, an additional 20,050 cubic yards of granular backfill was also added to the estimated costs. Since the original proposal was designed to adequately serve the area in an urbanized state, all other quantity estimates will remain unchanged.

The quantities of materials used in the preparation of the cost estimates are approximate, "being based almost wholly on sealed distances and other information from contour working maps."[16] The non-construction costs included in the estimate includes costs for the preparation of plans, contract documents, legal and administrative expenses, costs

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[16] Henry B. Steeg and Associates, Inc., op. cit., p. 27.

for obtaining rights-of-way, etc. These costs were assumed to be 20% of construction costs.

The average date of sale of the residences included in the benefit analysis was April, 1971. Therefore, the costs must be adjusted to April, 1971 also. Converting the total project costs required the use of the <u>Engineering News-Record</u> Sewerage Construction Cost Index,[17,18] which has a base year of 1957-1959=100.

$$\frac{170.4}{119.0} \quad \$1,787,832 = \$2,560,000$$

This total cost figure may now be divided by the total number of residences served to determine the average cost per residence.

$$\frac{\$2,560,000}{1089} = \$2,350$$

Hence, it is estimated that the cost to provide adequate storm drainage to the 38th Street and Columbus Avenue study area in a fully urbanized state averages approximately $2,350 per residence. An examination of the costs of proposals made for other residential areas in Anderson indicates that this figure is comparable to the other cost estimates; some

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[17] <u>Engineering New-Record</u>, "Sewerage Line Cost", Vol. 179, No. 25, December, 1967.

[18] <u>Engineering News-Record</u>, "Sewerage Construction Cost Index", Vol. 187, No. 25, December, 1971.

estimates being slighly lower per residence and some being slightly higher, depending on the characteristics of the area involved. Therefore, the per residence cost of $2350 estimated for the 38th Street and Columbus Avenue area is considered to be representative of the average per residence cost of providing storm drainage to residential areas of the City.

Costs of Drainage Correction and Economic Rent

Figure 4.5 illustrates the effect on economic rent of installing a storm drainage system at a cost of $2350 per residence. After the system is installed, the demand curve for residences in the area shifts upward from DD' to D_1D_1', reflecting the increased desirability of a well-drained residence. The demand curve shift resulted in an increase in the property of about $1763. Hence, the total economic rent is now represented by the area OA'B'$\bar{Q}$, an increase in economic rent represented by the area AA'B'B. The cost necessary to achieve the demand shift, however, amounts to $2350 per residence. Thus, the economic rent decreases by that amount per residence, or from OA'B'$\bar{Q}$ to OA"B"$\bar{Q}$ for the entire area. Hence, the cost per residence to install the storm drainage system has more than offset the expected benefits. The net loss in economic rent is equal to the area A"ABB". The loss per residence is $587, or $639,243 for the entire 38th Street and Columbus Avenue area.

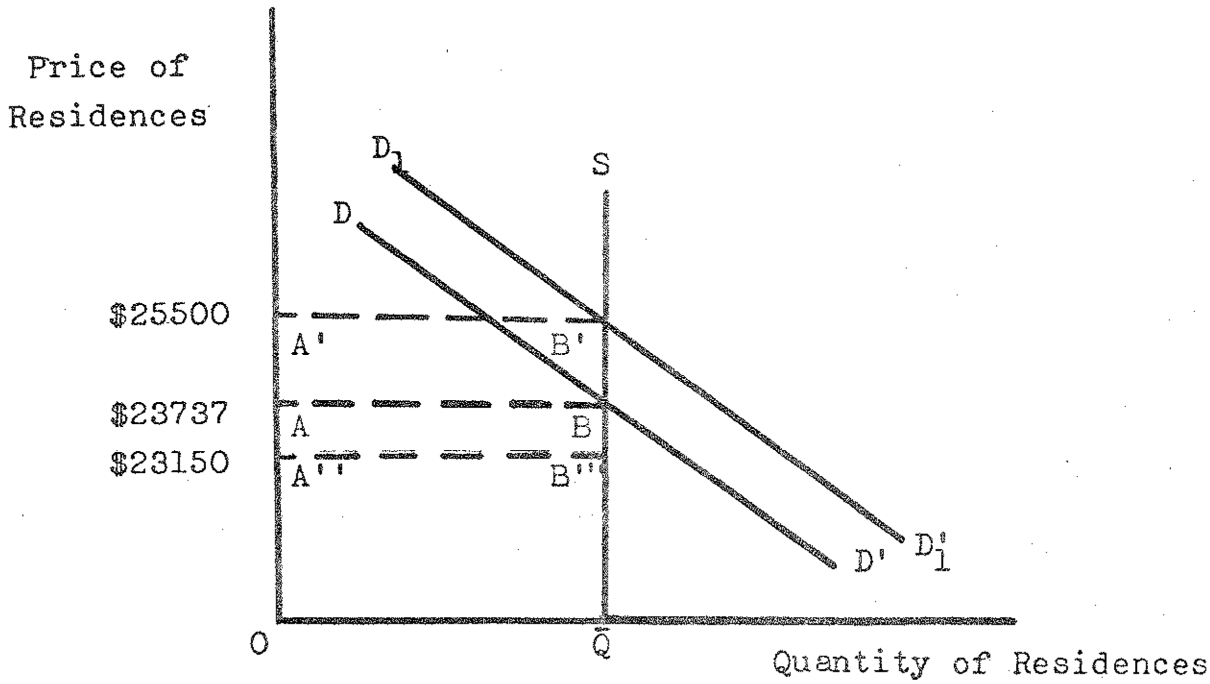

Figure 4.6. Effect of Storm Drainage Costs on Economic Rent

A somewhat different outcome may have resulted if the costs would have been estimated for installing the system before urbanization had taken place. There would be a reduction in the installation costs equal to the cost of tearing up and repairing the streets. Again using the 38th Street and Columbus Avenue area as the study area, and referring to Figure 4.3, it is found that approximately $427,332, or 23.9%, of the total estimated project costs would not have been included in the cost estimate, had the area not been urbanized. The total project cost, then, would be reduced to $1,360,500.

The expected total cost in April, 1971 dollars is:

$$\frac{170.4}{119.0} \quad \$1,360,500 = \$1,948,141$$

Dividing the total cost figure by 1089 residences indicates a per residence cost of $1789 for installing the system prior to urbanization. This is approximately $561 per residence lower than the estimate made for the same area after urbanization was complete.

Figure 4.6 illustrates the effect on economic rent of installing the drainage system before urbanization. Again the demand curve shifts upward from DD' to D_1D_1' as storm sewers are provided, the total quantity of economic rent being OA'B'$\bar{Q}$. The cost necessary to achieve the demand shift is, in this case, $1789 per residence. This decreases economic

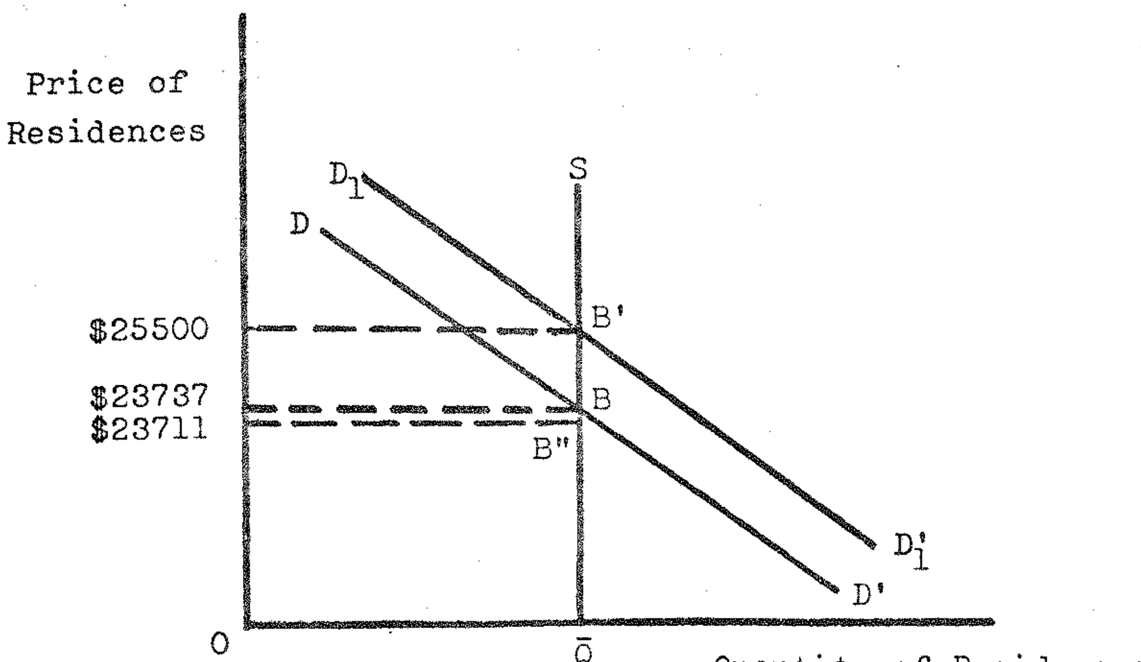

Figure 4.7. Effect on Economic Rent of Providing Storm Drainage Prior to Urbanization

rent by the area AA'B'B. The total economic rent remaining is now represented by the area OA"B"$\bar{Q}$. Hence, the cost to provide storm drainage prior to urbanization is nearly identical to the expected benefits. It has been found, then, that installing storm drainage facilities in flood-prone areas, which will be developed for residential use in the future, is economically justified, assuming some societal benefits, other than those accruing directly to homeowners, are expected.

These results must be interpreted carefully. Several assumptions have been made throughout the analysis that could affect the results. Initially, it was necessary to assume that home-buyers acted with perfect information concerning the drainage adequacy in a given area and that, given this information, they acted in a rational way. It is not known to what extent this assumption is actually met. It is the suspicion of real estate appraisers acquainted with the drainage problems in Anderson that some home-buyers are not fully aware of the drainage problem when they purchase property located in flood-prone areas. They suspect that some of those selling homes in poorly drained areas do so during the dryer parts of the year when the effects of poor drainage are least visible and, therefore, that little or no discount on the sale price of the property is made.

Apparently, other buyers knew of the drainage problem when they purchased their property, but were led to believe that the necessary drainage facilities were to be installed in the near fut and, therefore, that the problem was strictly a temp ary one. Regardless of the validity of this claim, this inf mation would result in an underestimate of the damage figure that this analysis sought to measure. This study intended to measure the home-buyers estimate of the present value of the expected future stream of damages with no expectation of drainage relief. Home-buyers expecting drainage correction in the near future would discount the property by the present value of the expected damages for only those years until the drainage facilities were expected to be installed.

It is also important to remember at this point that even if home-buyers did enjoy perfect information and were not mislead, the damage estimate is accurately reflecting only those future damages that the home-buyer himself expects to incur. The damage estimate, then, reflects only the value of physical and aesthetic property damages and inconveniences expected to be sustained by the homeowner. The value of damages to city streets and damages in the form of inconvenience to detoured motorists were not specifically dealt with in this study. It is reasonable to assume, however, that the homeowner would sustain the bulk of damages incurred by motorists in a residential area. The value of these damages is included in the existing damage estimate.

All of the possible distortions mentioned above would cause the damage estimate to be biased downward. It is difficult to make any further judgement as to the magnitude of the bias since it is difficult to know to what extent the assumption of perfect information has been violated or to estimate the value of damages which are external to the homeowner. It can be said, however, that the damage estimate made by use of the regression model represents the lower bound of the actual damages being sustained as a result of the residential flooding problem.

CHAPTER V

SUMMARY AND CONCLUSIONS

INTRODUCTION

Public planners and officials are continually confronted with the problem of evaluating the feasibility and efficiency of a wide range of public policies and programs. Both the benefits afforded by a given proposal and the costs necessary to implement that proposal are necessary information to consider in the decision-making process. A comparison of the benefits and the costs provides a measure of the efficiency of a particular proposal and may serve as a criterion when choosing from among a number of alternative proposals. This study was designed to estimate and compare the benefits and the costs of providing adequate storm drainage facilities to flood-prone urban residential areas.

The concept of economic rent was used to illustrate the estimated benefit or loss associated with the provision of adequate storm drainage facilities. In the case of a perfectly inelastic supply curve, as is the case in residential housing, economic rent is equal to the price. Hence, the increase in selling price of a residence due to the provision of adequate storm drainage facilities is analygous to the increase in economic rent. The cost to provide the drainage system is equal to the expected loss in economic rent. The net change in economic rent is simply the expected total gain in economic rent minus the expected total loss.

The first objective of this study was to estimate the benefits that would result from installing adequate storm drainage facilities. This objective was accomplished through the use of a linear regression model. The model was used to estimate the amount that home-buyers discount the sale value of residences located in inadequately drained residential areas of Anderson, Indiana. This value is equal to the discounted value of the home-buyers expected stream of future damages which are attributable to the flooding hazard. The expected damages were then interpreted as the benefits of eliminating the hazard.

The cost data was provided by a storm drainage study done for the City of Anderson by an engineering consulting firm in 1967. The drainage proposal made for the 38th Street and Columbus Avenue area, an area found to be representative of most residential areas of the City, was chosen as the cost study area. The costs to install the drainage system in this area were then calculated on a per residence basis. This allowed the costs to be strictly comparable with the benefits since both were estimated on the same basis. The presentation and discussion of the benefit-cost comparison fulfilled the second objective.

The third objective involved estimating and comparing the benefits and costs of providing storm drainage in an unurbanized area with the benefits and costs of providing storm drainage in an area where urbanization was complete. To accomplish this objective, the costs that would be incurred only in an urbanized area, i.e. street repair and granular backfill, were deleted from the cost estimate and the cost per residence was calculated again. The result gave an indication of the additional cost required to postpone the installation of storm drainage facilities until after an area becomes fully urbanized. This provides planners a basis with which to evaluate the advantages of providing drainage facilities before urbanization has been completed in an area.

Results

The first section of this analysis involved the estimation of home-buyers expected future flooding damages which are attributable to inadequate drainage. This required explaining, or holding constant, as much of the variation in property value that is not a function of drainage adequacy as possible in order to isolate the effect of drainage adequacy on property value. The linear regression model used for this purpose was successful in explaining approximately 81% of the variation in property values, using 11 independent, or explanatory, variables in the final model. The independent variables included in this model were: house size, number of garage spaces, date of sale, age of house, extras included in sale, quality of house, number of baths, existence of air-conditioning, existence of a fireplace, type of construction, and existence of a drainage problem. The F-test and the standard error of each variable indicated that 9 of the 11 variables were highly significant in explaining the variation in residential property values. The sign and magnitude of each of the variables was consistent with a priori expectations and with other models used for similar purposes. It was determined by an examination of the correlation matrix that high intercorrelation among independent variables was not a problem in the estimated model. In addition, it is believed that no significant explanatory variable was excluded from the model that could have significantly improved the models explanatory capabilities.

The estimated coefficient of the dummy variable denoting drainage adequacy revealed that home-buyers have discounted those homes located in poorly drained residential areas of Anderson by an average of $1763 per residence. This damage estimate was found to be highly significant statistically, having a probability of 99.9% that the true estimate is not zero. Furthermore, this variable was not found to be closely correlated to any other independent variable in the model, nor was it believed that it may be closely correlated to any significant variable that may have been inadvertantly excluded from the model.

The regression model estimated one point on each of two different demand curves for residential housing in Anderson. The demand curve for those homes located in flood-free areas crosses the inelastic supply curve at a higher point than does the demand curve for homes located in flood-prone areas. The vertical distance between the demand curves, as estimated by the regression model, is equivalent to a $1763 change in sale price. Hence, it was estimated that eliminating the drainage hazard will shift the demand curve upward, increasing the sale value of homes located in flood-prone areas by an average of $1763. Since the supply of homes in a residential area may be considered to be fixed, this increase in sales value, times the number of residences in the area, is equal to the total increase in economic rent.

In the second section of the study, the costs to provide storm drainage facilities were calculated and compared with the benefits. Costs were adjusted to April, 1971 prices since this was the average date of sale of the homes included in the benefit analysis. The total cost of the drainage system proposed to serve the 38th Street and Columbus Avenue area, assuming the area was occupied completely by single-family residences, was estimated to be approximately $2,560,000 in April, 1971 dollars. This cost estimate included all material, labor, and miscellaneous costs associated with installing the proposed system. It did not include any treatment costs.

The area served by the 38th Street and Columbus Avenue drainage proposal encompasses approximately 458 acres. Of this, it was estimated that about 17.6% of the area was occupied by streets. It was assumed that the lots in this particular area would average 15,100 square feet. Hence, it was estimated that 1076 residences would be served by the 38th Street and Columbus Avenue proposal. Dividing the total estimated cost by the number of residences served indicated that it would cost an average of approximately $2350 per residence to install the proposed drainage system. It is believed that this estimate is representative of the cost to install drainage facilities in Anderson's residential areas.

It was shown in the first section of the analysis that providing storm drainage to a flood-prone residential area in Anderson will shift the demand curve for the affected homes upward, resulting in an increase in economic rent averaging $1763 per residence. The costs necessary to provide the drainage, however, were estimated to be $2350 per residence, thus reducing economic rent by that amount. Therefore, the net reduction in economic rent associated with providing adequate storm drainage to urbanized flood-prone residential areas of Anderson was estimated to be approximately $587 per residence.

The third section of this analysis estimated the cost differential between providing the storm drainage system before and after urbanization. The costs of tearing up and repairing streets and the costs of granular backfill would not be incurred before urbanization. These costs accounted for $427,332, or 23.9% of the total cost estimate made for the urbanized area. Thus, the per residence cost of installing the drainage system prior to urbanization was $1789 per residence. Hence, the benefits of installing the drainage system prior to urbanization were found to be nearly equal to the costs.

Policy Implications

The results of this analysis suggest some interesting public policy implications. A comparison of the benefits and the costs revealed that the benefits of providing adequate storm drainage facilities to residences situated in existing inadequately drained residential areas of Anderson is more than offset by the installation costs. Therefore, the results suggest that extending storm drainage facilities to these areas is not economically justified. The question remains, however, as to the value of damages not accruing to the homeowners, but which are incurred by other members of society. These damages, which are mainly in the form of inconvenience to detoured motorists and damages to city streets, were not specifically evaluated in this analysis, but possibly could change the results and implications of the study.

A comparison of the benefits and costs of providing storm drainage <u>prior to</u> urbanization resulted in a more favorable ratio of benefits to costs. The homeowner benefits were found to be nearly equal to installation costs in this case. Assuming that some benefits will accrue to members of society other than those accruing directly to homeowners, the results suggest that installing drainage facilities in flood-prone areas prior to urbanization is economically justified. It is important, then, for city planners to closely monitor the residential development patterns within the city in order to identify potential problem areas before the areas are developed for residential use. This will allow the city to provide drainage systems, where required, prior to development, thereby minimizing future residential flooding damages.

Limitations of Research

Certain aspects of this study relating to the theory, the procedures, and the data base, serve as limitations to the results and conclusions. The use of the case study approach severely limits the general applicability of the results. Because of the many variables involved in estimating the benefits and the costs, the results tend to be valid and useable only for the study area itself. It is possible, however, to use a similar approach to evaluate the benefits and costs of a storm drainage system in a different area.

Some suspicion does exist concerning a theoretical assumption made at the outset of this study which could significantly affect the results. Initially, it was assumed that perfect information exists in the housing market and, therefore, that the price of a residence is a valid indicator of the utility, or satisfaction, derived from it. There is some suspicion that the assumption of perfect information, which is necessary for perfect competition to exist, was not in every case met. For example, it is suspected that some of those selling homes in flood-plagued residential areas tend to do so during the dryer parts of the year when the effects of poor drainage are least visible. To the extent that this suspicion is true, it would be expected that the estimate made of the benefits of storm drainage would tend to be biased downward. If the bias was large, the results of the study could be significantly affected.

Some limitations also exist concerning the methodology used to estimate the benefits. By using the differential in sale value between residences located in flood-prone and flood-free areas as the benefit estimate, some of the benefits of adequate drainage are obviously excluded. Assuming that home-buyers enjoy perfect information, the sale value differential represents only the present value of the future damages that the home-buyer himself expects to incur. A damage, which is not included in the home-buyers estimate, is the increased incidence of repair required by flooded city streets. Considering the high cost of street repair, the value of such damages, when summed over the life of the drainage system, could be quite significant. Also, damages in the form of inconvenience to motorists forced to periodically detour around flooded streets were not specifically examined in this study. It is believed, however, that the bulk of these damages is sustained by the homeowners in the affected residential areas and, therefore, that most of these damages are already included in the damage estimate.

The issue of environmental quality as it relates to adequate storm drainage also has not been dealt with in this study. Storm runoff is known to be an important carrier of pollutants to rivers and streams. Therefore, where severe pollution problems exist, storm drainage may be justified solely by environmental benefits without regard to the homeowner benefit-cost ratio. The importance given to environmental effects is highly subjective and was not within the scope of this study.

The method used to estimate the costs of providing drainage also could be a limiting factor to the results of this analysis. By choosing one residential area in the city to be used as the cost analysis study area, it must be assumed that the area chosen is representative of all residential areas of the city for which storm drainage projects are proposed. In a small city, such as Anderson, having relatively homogenous topographic, soil, and housing characteristics, this method is believed to be appropriate. However, such a procedure would not be appropriate for most larger cities where distinct changes in general characteristics exist between different residential sections of the city. The same limitation exists for smaller cities in which the areas proposed for storm drainage are not similar in residential characteristics.

The components of the cost estimate provide additional restrictions to the results of this study. Since only the higher cost pipeline drainage design was included in this analysis, the cost estimate is biased upward for those residential areas where an open-channel system or a combination of systems is feasible. If the lower cost open-channel system would have been used in this study, a more favorable benefit-cost ratio would have resulted. However, the cost estimate used in this study does not include the additional outlays that would be required if storm runoff were directed through a treatment facility before final disposal. Since storm runoff is an important source of non-point pollution, it may be required that storm runoff be treated in the future. This would require that the drainage costs be expanded to include treatment costs also. Therefore, the relevant runoff disposal costs vary depending on the particular disposal methods that are required in each area. The cost estimate made in this study was intended to accurately represent only those disposal costs which are incurred using the most common disposal methods in residential areas at this time.

Possibilities for Further Research

A comparison of the damages estimated by this study with the damage estimates made by insurance companies having flood insurance policies in the Anderson area would be useful in testing the accuracy of this damage estimate. It must be realized when comparing these estimates, however, that they are not identical with repect to the damages that were estimated. The damages sustained by the homeowner in the form of aesthetic and environmental deterioration are not included in insurance damage estimates, although they are included in the damages estimated in this study. However, since little or no previous work has been done with estimating the flooding damages that result from inadequate storm drainage, this comparison will allow some initial observations to be made concerning the overall reliability of the results and conclusions of this study.

Research designed to obtain information regarding the value of damages incurred by members of society other than homeowners as a result of inadequate storm drainage would also be extremely useful. If the damages of inconvenience to detoured commuting motorists and the damages to flooded city streets were estimated and added to the homeowners estimate, a more accurate damage estimate could be provided.

Additional study also could be done to test the validity of the perfect information assumption. Information necessary to determine how knowledgeable people purchasing homes in flood-prone areas typically are with regard to the drainage situation could be obtained via interviews and/or questionaires. This would be useful in estimating the degree to the damage estimate made in this analysis is biased, if any, and allow any necessary adjustments to be made.

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APPENDIX A

Appendix Table A-1 Simple Correlation Coefficients Between Variables Included in Model I.

Variables	PR	DA	SZ	AG	BA	GA
DA	.18714					
SZ	.73082	-.07331				
AG	-.47346	-.02195	-.28733			
BA	.66489	.02405	.67468	-.29883		
GA	.55683	-.05780	.41769	-.24667	.45066	
BS	.14810	.00685	.27696	.02951	.02329	.00047
AI	.14077	-.15616	.10909	.01711	.05524	-.06041
LO	.36414	-.05685	.40284	-.15987	.28459	.30157
FP	.26810	.06819	.26266	-.00970	.23556	.17829
EX	.39257	.11547	.28866	-.02601	.35756	.13431
SD	.39353	.04453	.24950	-.20856	.26939	.37697
QU	.51999	.01128	.46364	-.18583	.47231	.25003
WT	-.09307	.07429	-.10213	-.02236	-.03432	.17345

Appendix Table A-1 (cont'd)

Variables	BS	AI	LO	FP	EX	SD	QU
AI	.02495						
LO	.12406	.03047					
FP	.09433	.01150	.24797				
EX	.21831	.26778	.14414	.06452			
SD	.04252	.07312	.32050	.10066	.17127		
QU	.15303	.20349	.29296	.14867	.36087	.31934	
WT	-.07851	-.16908	.08265	.05460	-.03359	.13937	-.00350

* See text page 44 for definitions of the variables.

Appendix Table A-2 Simple Correlation Coefficients Between Variables Included in Model II.

Variables	PR	DA	SZ	AG	BA	GA
DA	.19771					
SZ	.73689	-.07613				
AG	-.47346	-.00407	-.27819			
BA	.67368	.02419	.67339	-.28106		
GA	.55683	-.06500	.41434	-.24667	.44307	
AI	.14077	-.14985	.11264	.01711	.06149	-.06041
FP	.26810	.07599	.26695	-.00970	.24259	.17829
EX	.39257	.13568	.29944	-.02601	.37626	.13431
SD	.39353	.04084	.24775	-.20856	.26532	.37697
QU	.51999	.01544	.46624	-.18583	.47551	.25003
WT	-.09307	.08136	-.09857	-.02236	-.02757	.17345

Appendix Table A-2 (cont'd)

Variables	AI	FP	EX	SD	QU
FP	.01150				
EX	.26778	.06452			
SD	.07312	.10066	.17127		
QU	.20349	.14867	.36087	.31934	
WT	-.16908	.05460	-.03359	.13937	-.00350

* See text page 44 for definitions of the variables.

Appendix Table A-3 Mean and Standard Deviation of Variables Included in Model I.

VARIABLE	MEAN	STANDARD DEVIATION
PR	25499.5614	6026.7470
DA	15.6784	7.2903
SZ	1343.3099	293.6332
AG	6.3275	4.8517
BA	1.5585	.4434
GA	1.7485	.4862
BS	.0234	.1516
AI	.1871	.3912
LO	2.2749	.5945
FP	.2398	.4282
EX	2.0175	.6985
SD	.9298	.2562
QU	2.1170	.3885
WT	.2074	.4047

Appendix Table A-4 Mean and Standard Deviation of Variables Included in Model II.

VARIABLE	MEAN	STANDARD DEVIATION
PR	25499.5614	6026.7470
DA	15.5789	7.2784
SZ	1341.2047	293.3609
AG	6.3275	4.8517
BA	1.5526	.4441
GA	1.7485	.4862
AI	.1871	.3912
FP	.2398	.4282
EX	2.0175	.6985
SD	.9298	.2562
QU	2.1170	.3885
WT	.2047	.4047